MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXXI. FEBRUARY 10, 1911. No. 4

ANNUAL GENERAL MEETING.

SIR DAVID GILL, K.C.B., F.R.S., PRESIDENT, in the Chair.

The Report of the Auditors of the Treasurer's accounts for the year 1910 was read, and is given on p. 244.

The Annual Report of the Council was partly read; see pp. 241 to 261.

The Address was delivered by the President, after which the Gold Medal was handed to Dr. P. H. Cowell, to whom it had been awarded "for his Contributions to the Lunar Theory and Gravitational Astronomy"; see pp. 368 to 380.

The President then delivered a further Address, which is given on pp. 380 to 385.

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year. The names of those elected are given on p. 386.

Mr. F. W. Dyson then took the chair as President.

The thanks of the Meeting were given to the retiring Members of Council, and also to the Auditors of the Treasurer's accounts and to the Scrutineers of the ballot.

Robert R. Agnew, M.A., Senior Science Master, Pupil Teachers' Institute, 15 Roxburgh Street, Kelvinside, Glasgow;

William Barnett, National Club, 1 Whitehall Gardens, S.W., and Laprida 1563, Rosario, Argentine Republic;

Rev. Edward Bruce Kirk, David Elder Lecturer on Astronomy, Glasgow Technical College, Barrhead, Scotland;

Arthur James Coleman, Lieut. R.N.R., R.D., Port Officer and Marine Magistrate, Malacca, Straits Settlements, and Frithville, Queen's Road, Horley, Surrey;

Thomas Francis Connolly, M.Sc., Solar Physics Observatory, South Kensington, and Kent House, Peterborough Road, Parson's Green, S.W.; and

Alexander D. Ross, M.A., B.Sc., F.R.S.E., Lecturer on Natural Philosophy in the University of Glasgow, 7 Queen's Terrace, Glasgow,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Archibald S. Dunlop, Major, Royal Field Artillery, Chief Instructor in Topography, Royal Military Academy, Woolwich (proposed by Major E. H. Hills);

Le Comte A. de Gramont, Docteur ès Science Physiques, 179 rue de l'Université, Paris, VII. (proposed by Sir David Gill); and

Patrick Henry Hepburn, LL.B. (Lond.), Solicitor, 49 Downshire Hill, Hampstead, N.W. (proposed by Neville Holden).

Report of the Council to the Ninety-first Annual General Meeting of the Society.

Addresses to His Majesty the King and Her Majesty Queen Alexandra.

The Council have pleasure in announcing that His Majesty King George V. was graciously pleased to accept the Address of Condolence and Homage, the text of which was printed in vol. lxx. p. 524. The Address was presented by the President, two Vice-Presidents, the Treasurer, and two Secretaries, and was received by His Majesty in person at St. James's Palace on June 22, 1910.

The Address of Condolence printed in vol. lxx. p. 525, was sent to Her Majesty Queen Alexandra, and graciously accepted.

On July 18 a letter was received from Lieut.-Colonel Sir William Carington, Keeper of H.M. Privy Purse, announcing that His Majesty had graciously consented to become the Patron of the Society.

His Majesty the King has also been graciously pleased to sign the Roll of the Society.

The following table shows the progress and present state of the Society:—

	Patron	Honorary Members	Fellows		Associates	Total
			Compounders	Annual Subscribers		
1909 December 31	1	2	261	421	47	732
Since elected	...	...	...	+40	+3	...
Deceased	...	...	−7	−9	−2	...
Resigned	...	...	...	−3	...	...
Since compounded	...	...	+3	−3	...	...
Removed	...	...	...	−4	...	...
1910 December 31	1	2	257	442	48	750

Major Hills' Account as Treasurer of the Royal

RECEIVED.

	£	s.	d.	£	s.	d.
Balances, 1909 December 31 :—						
At Bankers', as per Pass-book	491	0	5			
Cheque not credited	14	12	0			
In hand of Assistant Secretary on Petty Cash Account	5	5	4			
				510	17	9
Dividends :—						
£1,250 Metropolitan 3-per-cent. Stock ...	35	6	4			
£2,000 Swansea Corporation 3½-per-cent. Stock	65	18	4			
£3,500 East Indian Railway 3-per-cent. Debenture Stock	98	17	4			
£3,500 London and North-Western Railway 3-per-cent. Debenture Stock	98	17	6			
£4,000 Midland Railway 2½-per-cent. Debenture Stock	94	3	4			
£500 Lancashire and Yorkshire Railway 3-per-cent. Preference Stock	14	2	6			
£2,000 Gas Light and Coke Co. 3-per-cent. Debenture Stock	56	10	0			
£2,000 Commercial Gas Co. 3-per-cent. Debenture Stock	61	8	10			
				525	4	2
Interest on money on deposit at Bankers'				8	8	10
Received on account of Subscriptions :—						
Arrears	163	12	0			
Annual Contributions for 1910	638	8	0			
,, ,, for 1911 in advance	6	6	0			
Admission Fees	86	2	0			
First Contributions	64	1	0			
				958	9	0
Composition Fees...				68	5	0
Sales of Publications :—						
At Williams & Norgate's, 1909	20	18	6			
At Society's Rooms, 1910	101	12	10			
Sales of Photographs, 1910	76	13	0			
				199	4	4
Income Tax refunded by Commissioners of Inland Revenue				30	18	8
Cheques outstanding, December 31, 1910				16	19	6
Due to Assistant Secretary on Petty Cash Account					15	8
				£2,319	2	11

Examined and found correct, January 9, 1911.

F. W. Levander.
W. E. Rolston.
Richard Inwards.

Astronomical Society from January 1 to December 31, 1910.

PAID.

	£ s. d.	£ s. d.
Assistant Secretary: Salary	250 0 0	
,, ,, Editing Society's Publications	50 0 0	
Clerk's Salary	100 0 0	
		400 0 0
House Duty	2 12 6	
Fire and Servants' Insurance	9 12 6	
		12 5 0
Printing, etc.:—		
Monthly Notices	375 14 5	
Memoirs, Vol. 59, Part 4	24 9 4	
Miscellaneous Printing	29 6 0	
Photo-Engraving	34 0 2	
		463 9 11
Reproduction of Photographs for sale		98 9 2
Cataloguing Astronomical Literature for the International Catalogue of Scientific Literature ...		30 0 0
Turnor and Horrox Fund, purchases for Library ...	22 16 4	
Council Grant for ,, ,,	20 0 0	
		42 16 4
Subsn. to *Centralstelle für astronomische Telegramme*	2 10 9	
Telephone: Subscription and Deposit	7 10 0	
Registration of Telegraphic Address	1 1 0	
		11 1 9
Expenses of Meetings	19 14 11	
Lantern expenses	4 10 0	
Time Signal: rental of wire	5 0 0	
		29 4 11
Postage and Telegrams	100 4 3	
Carriage of Parcels	2 18 4	
Stationery and Office expenses	20 5 0	
		123 7 7
House expenses: Allowance and sundry expenses	60 8 3	
Coal and Gas	50 0 9	
Electric Lighting	23 8 2	
Fittings and Decorations	77 10 6	
Sundry Fittings and Repairs	18 19 5	
Sundries	6 8 6	
		236 15 7
Engrossing Addresses to His Majesty the King and Her Majesty Queen Alexandra		6 0 0
Contribution towards Cost of Measuring an Arc of Meridian in Uganda		25 0 0
Purchase of £350 Commercial Gas Co. 3-per-cent. Debenture Stock @ 82½, including Commission	291 17 6	
Purchase of £500 Lancashire and Yorkshire Railway 3-per-cent. Preference Stock @ 78⅝, including Commission	396 3 0	
		688 0 6
Due to Assistant Secretary on Turnor and Horrox Fund, December 31, 1909	1 8	
Cheque outstanding, December 31, 1909	7 10 0	
		7 11 8
Deductions on cheques		3 7
Balances, December 31, 1910:—		
At Bankers', as per Pass-book	138 12 11	
Cheque not credited	2 2 0	
In hand of Assistant Secretary on Account of Turnor and Horrox Fund	4 2 0	
		144 16 11
		£2,319 2 11

Report of the Auditors.

We have examined the Treasurer's account of receipts and expenditure for the year 1910, and have found and certified the same to be correct. The cash in hand on December 31, 1910, including the balance at the bankers', etc., amounted to £144 16*s.* 11*d.*

The funded property of the Society has been increased by the purchase of £350 Commercial Gas Company 3-per-cent. Debenture Stock and £500 Lancashire and Yorkshire Railway 3-per-cent. Consolidated Preference Stock.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition.

A list has been laid on the table of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, together with the amount due against each Fellow's name.

F. W. Levander.
W. E. Rolston.
Richard Inwards.

1911 *January* 9.

Gifts to the General Funds of the Society.

In 1836 John Lee, Esq., LL.D., gave the Advowson of the living of Hartwell; in 1844 he gave the Advowson of the living of Stone. In 1879 these Advowsons were repurchased by his heir, Edward Lee, Esq., for £700.

The Lawson Bequest (1856): Henry Lawson, Esq., bequeathed to the Society the sum of £200, free of legacy duty.

The Carrington Bequest (1876): R. C. Carrington, Esq., F.R.S., bequeathed to the Society £2,000 Consols. This was sold in 1899, and stands now in £1,881 14*s.* London and North-Western Railway 3-per-cent. Debenture Stock.

The Lambert Bequest (1877): C. J. Lambert, Esq., presented to the Society the sum of £500, free of legacy duty, being part of a sum of money bequeathed by his father, Charles Lambert, Esq., for scientific purposes.

The McClean Bequest (1905): Frank McClean, Esq., LL.D., F.R.S., bequeathed to the Society the sum of £2,000, free of legacy duty. This now stands in £1,871 1*s.* 6*d.* Swansea Corporation 3½-per-cent. Stock.

The Farrar Bequest (1906): The Rev. A. S. Farrar, D.D., bequeathed to the Society the sum of £100, free of legacy duty. This now stands in £93 11*s.* 1*d.* Swansea Corporation 3½-per-cent. Stock.

Trust Funds.

The Lee and Janson Fund: In 1834 John Lee, Esq., LL.D., gave £100, and in 1876 T. C. Janson, Esq., bequeathed £200, the interest to be given to the widow or orphan of a deceased Fellow. These amounts now stand in £334 10*s.* 9*d.* East Indian Railway 3-per-cent. Debenture Stock.

The Turnor Fund and the Horrox Memorial Fund: In 1853 the Rev. Charles Turnor, M.A., bequeathed a sum of £500, which now stands in £464 18*s.* East Indian Railway 3-per-cent. Debenture Stock. In 1876 the Society received a sum of £38 15*s.*, the unexpended balance of a fund collected for the purpose of erecting a memorial in Westminster Abbey to Jeremiah Horrox: to this the Society added the sum of £55 15*s.*, and the whole now stands in £103 6*s.* East Indian Railway 3-per-cent. Debenture Stock. The interest on these funds is to be used in the purchase of books for the Library.

The Hannah Jackson (née Gwilt) Fund: In 1861 Mrs Hannah Jackson (*née* Gwilt) gave £300 Consols, which now stands in £309 18*s.* 6*d.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be given in medals or other awards in accordance with the terms of the Trust.

Assets and Present Property of the Society, 1911 January 1.

	£	s.	d.	£	s.	d.	£	s.	d.
Balances, 1910 December 31 :—									
At Bankers', as per Pass-book ...	138	12	11						
Cheque not credited till 1911 ...	2	2	0						
In hand of Assistant Secretary on account of Turnor and Horrox Fund	4	2	0						
				144	16	11			
Less Cheques outstanding	16	19	6						
,, due to Assistant Secretary on Petty Cash Account ...	0	15	8						
				17	15	2			
							127	1	9
Due on account of Subscriptions :—									
11 Contributions of 3 years' standing	69	6	0						
37 ,, 2 ,, ,,	163	16	0						
75 ,, 1 ,, ,,	157	10	0						
3 Admission Fees and First Contributions	10	10	0						
				401	2	0			
Less 3 Contributions paid in advance ...				6	6	0			
							394	16	0
Due for Publications				7	0	0			
,, for Photographs				3	19	0			
							10	19	0
,, from Williams & Norgate for Publications sold during 1910							23	0	1

£1,250 Metropolitan 3-per-cent. Stock.

£2,000 Swansea Corporation 3½-per-cent. Stock (including the McClean and Farrar Bequests).

£3,500 East Indian Railway 3-per-cent. Debenture Stock (including the Turnor Fund, the Horrox Memorial Fund, the Lee and Janson Fund, and the Hannah Jackson (*née* Gwilt) Fund).

£3,500 London and North-Western Railway 3-per-cent. Debenture Stock (including the Carrington Bequest).

£4,000 Midland Railway 2½-per-cent. Debenture Stock.

£1,000 Lancashire and Yorkshire Railway 3-per-cent. Consolidated Preference Stock.

£2,000 Gas Light and Coke Co. 3-per-cent. Debenture Stock.

£2,000 Commercial Gas Co. 3-per-cent. Debenture Stock.

Astronomical and other Manuscripts, Books, Prints, Photographs, and Instruments.

Furniture, &c.

Stock of Publications and Photographs.

One Gold Medal.

Celestial Photographs.

The following is a list of reproductions of Celestial Photographs published by the Royal Astronomical Society for sale to the Fellows:—

R.A.S. Ref. No.	Subject and Date.	Photographed by
1	Total Solar Eclipse, 1889 January 1	W. H. Pickering
2	Total Solar Eclipse, 1893 April 16	J. M. Schaeberle
3	Total Solar Eclipse, 1886 August 29	A. Schuster
4	Nebulæ in the *Pleiades*, 1888 December 8	Isaac Roberts
5	Nebula M 74 *Piscium* (N.G.C. 628), 1893 December 9	Isaac Roberts
6	Great Nebula in *Orion*, 1888 December 24	Isaac Roberts
7	Milky Way near M 11, 1892 June 29	E. E. Barnard
8	Milky Way near Cluster in *Perseus*, 1893 November 3	E. E. Barnard
9	Comet 1893 IV. (Brooks), 1893 October 21	E. E. Barnard
10	Comet 1892 I. (Swift), 1892 April 7	E. E. Barnard
11	Nebula about η *Argus*, 1892 March 3	David Gill
12	Portion of Moon (Hyginus-Albategnius), 1894 March 14	Loewy and Puiseux
13	Comet 1893 IV. (Brooks), 1893 October 22	E. E. Barnard
14	Comet 1893 IV. (Brooks), 1893 October 20	E. E. Barnard
15	Comet 1893 IV. (Brooks), 1893 November 10	E. E. Barnard

R.A.S. Ref. No.	Subject and Date.	Photographed by
16	Comet 1892 I. (Swift), 1892 April 26	E. E. Barnard
17	Comet 1892 III. (Holmes), 1892 November 10	E. E. Barnard
18	Comet 1892 I. (Swift), 1892 April 18	E. E. Barnard
19	Portion of Moon (Alps, Apennines, &c.), 1894 February 13	Loewy and Puiseux
20	Nebula in *Andromeda*, 1888 December 29	Isaac Roberts
21	*Jupiter*, 1892 September 26	Lick Observatory
22	Cluster M 13 *Herculis* (N.G.C. 6205), 1894 August 5	W. E. Wilson
23	Total Solar Eclipse, 1893 April 16 (5 sec.)	J. Kearney
24	Total Solar Eclipse, 1893 April 16 (20 sec.)	J. Kearney
25	The Moon (Age 7d. 3h.), 1890 September 21	Lick Observatory
26	The Moon (Age 12d. 6½h.), 1891 August 16	Lick Observatory
27	The Moon (Age 16d. 18h.), 1890 August 31	Lick Observatory
28	The Moon (Age 23d. 8h.), 1891 July 28	Lick Observatory
29	The Sun, 1892 February 13	Roy. Obs., Greenwich
30	The Sun, 1892 July 8	Roy. Obs., Greenwich
31	Portion of Moon (Region of Maginus), 1894 February 13	Loewy and Puiseux
32	The Moon (Age 14d. 1h.), 1890 October 27	Lick Observatory
33	Portion of Moon (Ptolemæus, &c.), 1895 October 9	Lick Observatory
34	Portion of Moon (Mare Serenitatis), 1895 October 7	Lick Observatory
35	Portion of Moon (Clavius, Licetus), 1895 October 8	Lick Observatory
36	Portion of Moon (Regiomontanus), 1895 October 8	Lick Observatory
37	Portion of Moon (Tycho, Thebit), 1895 October 9	Lick Observatory
38	Portion of Moon (Theophilus, &c.), 1895 October 7	Lick Observatory
39	Total Solar Eclipse, 1896 August 9 (3 sec.)	S. Kostinsky
40	Total Solar Eclipse, 1896 August 9 (26 sec.)	A. Hansky
41	Cluster M 56 *Lyræ* (N.G.C. 6779), 1896 May 9	
42	Nebulæ M 81, 82 *Ursæ Majoris* (N.G.C. 3031, 3034), 1896 May 10	
43	Cluster M 56 *Lyræ* (N.G.C. 6779) (enlarged), 1896 May 9	
44	Solar Corona, 1871 December 12, Baikul	H. Davis

R.A.S. Ref. No.	Subject and Date.	Photographed by
45	Solar Corona, 1875 April 6, Siam	Lockyer and Schuster
46	Solar Corona, 1878 July 29, Wyoming	W. Harkness
47	Solar Corona, 1882 May 17, Egypt	Abney and Schuster
48	Solar Corona, 1883 May 6, Caroline Island	Lawrance and Woods
49	Solar Corona, 1885 Sept. 9, Wellington, N.Z.	Radford
50	Solar Corona, 1886 August 29, Grenada, W.I.	A. Schuster
51	Solar Corona, 1887 August 19, Japan	M. Sugiyama
52	Solar Corona, 1889 January 1, California	W. H. Pickering
53	Solar Corona, 1889 December 22, Cayenne	J. M. Schaeberle
54	Solar Corona, 1893 April 16, Fundium	J. Kearney
55	Solar Corona, 1893 April 16, Brazil	A. Taylor
56	Great Nebula in *Orion*, 1897 January 23	W. E. Wilson
57	Dumb-bell Nebula, N.G.C. 6853, 1894 August 6	W. E. Wilson
58	Spiral Nebula, *Canes Venatici* (N.G.C. 5194–5), 1897 March 6	W. E. Wilson
59	Ditto (enlarged)	W. E. Wilson
60	Annular Nebula, *Lyra* (N.G.C. 6720), 1894 September 9	W. E. Wilson
61	Meteor Trail and Comet Brooks, 1893 Nov. 13	E. E. Barnard
62	Total Solar Eclipse, 1898 January 22 (5 sec.)	W. H. M. Christie
63	Total Solar Eclipse, 1898 January 22 (20 sec.)	W. H. M. Christie
64	Solar Corona, 1896 August 9, Novaya Zemlya	G. Baden-Powell
65	Solar Corona, 1898 January 22, Pulgaon, India	E. H. Hills
66	Nebula in *Andromeda*, 1898 September 23	Roy. Obs., Greenwich
67	Spectrum of Sun's Limb, 1898 January 22	E. H. Hills
68	Annular Nebula, *Lyra* (N.G.C. 6720), 1899 July 14	Lick Observatory
69	Dumb-bell Nebula, N.G.C. 6853, 1899 July 31	Lick Observatory
70	Spiral Nebula, *Canes Venatici* (N.G.C. 5194–5), 1899 May 10	Lick Observatory
71	Spiral Nebula, *Ursa Major* (N.G.C. 5457), 1899 June 8	Lick Observatory
72	Trifid Nebula, *Sagittarius* (N.G.C. 6514), 1899 July 6	Lick Observatory
73	Great Nebula in *Orion*, 1898 December 11	Lick Observatory
74	Cluster M 13 *Herculis* (N.G.C. 6205), 1899 July 13	Lick Observatory
75	Solar Surface with Faculæ, 1893 August 7	G. E. Hale
76	Faculæ and Prominences, 1892 June 25	G. E. Hale

R.A.S. Ref. No.	Subject and Date.	Photographed by
77	Total Solar Eclipse, 1898 January 22 (⅔ sec.)	W. H. M. Christie
78	Nebula H V.14 *Cygni* (N.G.C. 6992), 1899 October 7	W. E. Wilson
79	Portion of Moon (Theophilus, &c.), 1900 October 12	Yerkes Observatory
80	Total Solar Eclipse, 1900 May 28 (30 sec.)	E. E. Barnard
81	Comet 1901 I., 1901 May 4	Roy. Obs., Cape of G. H.
82	Comet 1901 I., 1901 May 6	Roy. Obs., Cape of G. H.
83	Comet 1901 I., 1901 May 9	Perth Obs., W. Australia
84	Solar Surface with Faculæ, 1895 August 18	H. Deslandres
85	Solar Prominences, 1894 April 11	H. Deslandres
86	Nebula about Nova *Persei*, 1901 Septem. 20	G. W. Ritchey
87	Nebula about Nova *Persei*, 1901 Novem. 13	G. W. Ritchey
88	Total Solar Eclipse, 1901 May 18 (10 sec.)	F. W. Dyson
89	Total Solar Eclipse, 1901 May 18 (40 sec.)	F. W. Dyson
90	Comet 1902 III. (Perrine), 1902 Septem. 29	Roy. Obs., Greenwich
91	Portion of Moon (Mare Serenitatis), 1901 August 3	Yerkes Observatory
92	Portion of Moon (Mare Nubium, &c.), 1901 November 21	Yerkes Observatory
93	Portion of Moon (Tycho, Theophilus), 1900 October 12	Yerkes Observatory
94	Portion of Moon (Bullialdus, Copernicus), 1901 November 20	Yerkes Observatory
95	Portion of Moon (Copernicus, enlarged), 1901 November 20	Yerkes Observatory
96	Great Nebula in *Orion*, 1901 October 19	Yerkes Observatory
97	Ditto (Central portion), 1901 January 20	Yerkes Observatory
98	Nebula in *Andromeda*, 1901 September 18	Yerkes Observatory
99	Nebula in *Cygnus* (N.G.C. 6960), 1902 August 1	Yerkes Observatory
100	Nebula H V. *Cygni* (N.G.C. 6992), 1901 October 5	Yerkes Observatory
101	Cluster M 13 *Herculis* (N.G.C. 6205), 1901 April 25	Yerkes Observatory
102	Cluster M 15 *Pegasi* (N.G.C. 7078), 1900 October 3	Yerkes Observatory
103	Solar Surface with Faculæ, 1903 April 27	Yerkes Observatory
104	The Moon, 1900 April 5	P. Puiseux
105	The Moon, 1902 November 13	P. Puiseux

R.A.S. Ref. No.	Subject and Date.	Photographed by
106	The Moon, 1903 February 6	P. Puiseux
107	The Moon, 1903 September 12	P. Puiseux
108	Nebulosity about 15 *Monocerotis*, 1894 February 1	E. E. Barnard
109	Milky Way about β *Cygni*, 1893 October 12	E. E. Barnard
110	Nebulosity near α *Cygni*, 1893 October 5	E. E. Barnard
111	Milky Way near χ *Cygni*, 1892 October 20	E. E. Barnard
112	Star Cloud in *Sagittarius*, 1892 June 20	E. E. Barnard
113	Milky Way in *Cepheus*, 1893 October 13	E. E. Barnard
114	Milky Way about M 8, 1894 July 5	E. E. Barnard
115	Milky Way about θ *Ophiuchi*, 1894 July 6	E. E. Barnard
116	Milky Way near N.G.C. 6475, 1894 July 26	E. E. Barnard
117	Great Nebula near ρ *Ophiuchi*, 1895 June 21–2	E. E. Barnard
118	Milky Way about 58 *Ophiuchi*, 1895 June 26	E. E. Barnard
119	Milky Way near *Omega* nebula, 1895 July 25	E. E. Barnard
120	Star Cloud in *Sagittarius*, 1895 August 13	E. E. Barnard
121	Nebula about ν *Scorpii*, 1895 May 23	E. E. Barnard
122	Sun, 1905 January 30	Roy. Obs., Greenwich
123	Sun-spot, 1905 January 30	Roy. Obs., Greenwich
124	Sun, 1905 January 31	Roy. Obs., Greenwich
125	Sun-spot, 1905 January 31	Roy. Obs., Greenwich
126	Sun, 1905 February 2	Roy. Obs., Greenwich
127	Sun-spot, 1905 February 2	Roy. Obs., Greenwich
128	Sun, 1905 February 3	Roy. Obs., Greenwich
129	Sun-spot, 1905 February 3	Roy. Obs., Greenwich
130	Sun, 1905 February 5	Roy. Obs., Greenwich
131	Sun-spot, 1905 February 5	Roy. Obs., Greenwich
132	Sun, 1905 February 8	Roy. Obs., Greenwich
133	Sun-spot, 1905 February 8	Roy. Obs., Greenwich
134	Nebula near ψ *Eridani*, 1905 January 8	Max Wolf
135	Nebula M 33 *Trianguli* (N.G.C. 598), 1895 November 14	Isaac Roberts
136	Nebula in *Perseus* (N.G.C. 1499), 1897 December 18	Isaac Roberts
137	Nebula in *Monoceros* (N.G.C. 2237–9), 1899 March 5	Isaac Roberts
138	Nebula H V. 24 *Comæ* (N.G.C. 4565), 1896 May 11	Isaac Roberts
139	Nebulæ H V. 42, &c., *Comæ* (N.G.C. 4631), 1894 March 29	Isaac Roberts

R.A.S. Ref. No.	Subject and Date.	Photographed by
140	Nebula H V. 37 *Cygni* (N.G.C. 7000?), 1896 October 10	Isaac Roberts
141	Nebula Index Cat. 405 *Persei*, 1902 January 14	Isaac Roberts
142	Clusters in *Perseus* (N.G.C. 869, 884), 1895 October 12	Isaac Roberts
143	Cluster H VI. 30 *Cassiopeiæ* (N.G.C. 7789), 1898 December 17	Isaac Roberts
144	Total Solar Eclipse, 1905 August 30 (5 sec.)	W. H. M. Christie
145	Total Solar Eclipse, 1905 August 30 (20 sec.)	W. H. M. Christie
146	Total Solar Eclipse, 1905 August 30 (7 sec.)	W. H. M. Christie
147	Total Solar Eclipse, 1905 August 30 (20 sec.)	W. H. M. Christie
148	Total Solar Eclipse, 1905 August 30 (Portion)	W. H. M. Christie
149	Region of Nebula ρ *Ophiuchi*, 1905 April 5	E. E. Barnard
150	Nebula ρ *Ophiuchi* (enlarged), 1905 April 5	E. E. Barnard
151	Region of θ *Ophiuchi*, 1905 June 5	E. E. Barnard
152	Great Rift near θ *Ophiuchi*, 1905 June 28	E. E. Barnard
153	Great Star Cloud in *Sagittarius*, 1905 June 29	E. E. Barnard
154	Small Star Cloud in *Sagittarius*, 1905 July 31	E. E. Barnard
155	Region of Cluster M 11, 1905 July 30	E. E. Barnard
156	Sun-spots, 1906 July 6	Roy. Obs., Greenwich
157	Sun-spot, 1906 July 31	Roy. Obs., Greenwich
158	Sun-spot, 1906 August 3	Roy. Obs., Greenwich
159	Eclipse, 1905 August 30 (large prominence)	De la Baume Pluvinel
160	Comet 1908 III. (Morehouse), Sept. 7d. 14h. 56m.	Roy. Obs., Greenwich
161	Comet 1908 III., Sept. 14d. 8h. 22m.	Roy. Obs., Greenwich
162	Comet 1908 III., Sept. 29d. 13h. 12m.	Roy. Obs., Greenwich
163	Comet 1908 III., Sept. 29d. 14h. 13m.	Roy. Obs., Greenwich
164	Comet 1908 III., Sept. 29d. 15h. 19m.	Roy. Obs., Greenwich
165	Comet 1908 III., Sept. 29d. 16h. 15m.	Roy. Obs., Greenwich
166	Comet 1908 III., Oct. 3d. 9h. 4m.	Roy. Obs., Greenwich
167	Comet 1908 III., Oct. 3d. 13h. 13m.	Roy. Obs., Greenwich
168	Comet 1908 III., Oct. 27d. 10h. 2m.	Roy. Obs., Greenwich
169	Comet 1908 III., Oct. 29d. 7h. 3m	Roy. Obs., Greenwich
170	Comet 1908 III., Oct. 30d. 7h. 47m.	Roy. Obs., Greenwich
171	Comet 1908 III., Nov. 3d. 6h. 43m.	Roy. Obs., Greenwich
172	Comet 1908 III., Oct. 1d. 8h. 55m.	Roy. Obs., Greenwich
173	Comet 1908 III., Oct. 30d. 6h. 56m.	Roy. Obs., Greenwich
174	Comet 1908 III., Sept. 30d. 20h. 57m.	E. E. Barnard
175	Comet 1908 III., Oct. 1d. 14h. 45m.	E. E. Barnard

R.A.S. Ref. No.	Subject and Date.	Photographed by
176	Comet 1908 III., Oct. 1d. 19h. 15m	E. E. Barnard
177	Comet 1908 III., Oct. 15d. 12h. 57m.	E. E. Barnard
178	Sun-spot Vortices, 1908 Oct. 7	G. E. Hale
179	Total Solar Eclipse, 1908 Jan. 3 (16 sec.)	W. W. Campbell
180	Comet 1908 III. (Morehouse), Oct. 16d. 15h. 32m.	E. E. Barnard
181	Comet 1908 III., Nov. 16d. 13h. 10m.	E. E. Barnard
182	Comet 1908 III., Nov. 19d. 6h. 4m.	Roy. Obs., Greenwich
183	Comet 1908 III., Nov. 22d. 5h. 55m.	Roy. Obs., Greenwich
184	Comet 1908 III., Nov. 25d. 5h. 55m.	Roy. Obs., Greenwich
185	Stellar spectra, types I., II., III.	Stonyhurst Observatory
186	Progressive spectra, types I. and II.	Stonyhurst Observatory
187	Spectrum of γ *Cassiopeiæ*	Stonyhurst Observatory
188	Spectra of o *Ceti*, 1897 and 1906	Stonyhurst Observatory
189	Spectra of o *Ceti* (1897) and α *Herculis* (1898)	Stonyhurst Observatory
190	Spectra of β *Aurigæ*, 1906	Stonyhurst Observatory
191	Spectra of *Nova Persei* (1901 Feb. 28) and *Castor* (Feb. 19)	Stonyhurst Observatory
192	Alternating spectra, *Nova Persei* (1901 March 21–28)	Stonyhurst Observatory
193	Titanium oxide flutings in o *Ceti*	A. Fowler
194	Stereogram, Comet 1908 III. (Morehouse, Oct. 15)	E. E. Barnard
195	Stereogram, Comet 1908 III. (Nov. 16)	E. E. Barnard
196	Stereogram, Comet 1908 III. (Nov. 18)	E. E. Barnard
197	Mars, 1909 October 5	G. E. Hale
198	Mars, 1909 November 3	G. E. Hale
199	Spectra of Moon and Major Planets	Lowell Observatory
200	4-prism Spectrograph of Newall Telescope	Cambridge Observatory
201	Spectra of high and low Sun	G. Higgs
202	Spectrum of α Persei, 1902 September 19	H. F. Newall
203	Spectra of Earliest Stars	W. Huggins
204	Spectra of Early Stars	W. Huggins
205	Spectra of Early Solar Stars	W. Huggins
206	Spectra of Pre-solar Stars	W. Huggins
207	Spectra of Solar and Post-solar Stars	W. Huggins
208	Spectra of Double Stars	W. Huggins
209	Spectra, Carbon arc and types III., IV.	G. E. Hale
210	Spectra, type IV. (blue region)	G. E. Hale
211	Spectra, type IV. (yellow and green region)	G. E. Hale
212	Spectra, types II., III., IV. (blue region)	G. E. Hale

R.A.S. Ref. No.	Subject and Date.	Photographed by
213	Spectra, Iron, Titanium and Chromium	Solar Physics Obsy.
214	Moon (S. Pole to Hipparchus)	G. E. Hale
215	Moon (N. Pole to Agrippa)	G. E. Hale
216	Comet 1910 I., January 27	Lowell Observatory
217	Halley's Comet, 1910 March 4	Helwân Observatory
218	Halley's Comet, 1910 April 16	Helwân Observatory
219	Halley's Comet, 1910 April 27	Helwân Observatory
220	Halley's Comet, 1910 May 4	E. E. Barnard
221	Great Nebula, *Orion* (central portion), 1909 September 16	G. W. Ritchey
222	Nebula in *Andromeda* (central portion), 1909 October 13	G. W. Ritchey
223	Spiral Nebula, *Canes Venatici* (N.G.C. 5194–5), 1910 February 7–8	G. W. Ritchey
224	Spiral Nebula, M. 101 *Ursæ Majoris* (N.G.C. 5457), 1910 March 10–11	G. W. Ritchey
225	Spiral Nebula, M. 81 *Ursæ Majoris* (N.G.C. 3031), 1910 February 5	G. W. Ritchey
226	Cluster M. 3 *Canes Venatici* (N.G.C. 5272), 1910 April 9	G. W. Ritchey
227	Annular Nebula, *Lyra* (N.G.C. 6720), 1910 September 17	G. W. Ritchey
228	Crab Nebula, *Taurus* (N.G.C. 1952), 1909 October 13	G. W. Ritchey
229	Owl Nebula, *Ursa Major* (N.G.C. 3587), 1910 February 9	G. W. Ritchey
230	Nebula, H. V. 24 *Comæ Beren.* (N.G.C. 4565), 1910 March 6–7	G. W. Ritchey
231	Spiral Nebula, M. 33 *Trianguli* (N.G.C. 598), 1910 August 5–7	G. W. Ritchey
232	Spiral Nebula, M. 64 *Comæ Beren.* (N.G.C. 4828) 1910 May 5–8	G. W. Ritchey
233	Nebula in *Cygnus* (N.G.C. 6960), 1910 July 4–5	G. W. Ritchey
234	Nebula in *Cygnus* (N.G.C. 6992), 1910 July 2–4	G. W. Ritchey

Nos. 44–55, Nos. 64, 65, and No. 147 form a series of corona photographs, oriented and reduced to the same scale.

The above photographs (excepting Nos. 194–196) are now on sale to Fellows as prints, either platinotype or aristotype, mounted

on sunk cut-out mounts, measuring 12 inches by 10 inches; also unmounted, and as lantern slides. Nos. 44–55 and Nos. 64 and 65 are also supplied as transparencies, $6\frac{1}{4}$ inches square.

Price of prints, mounted 1*s.* 6*d.* each, unmounted 1*s.* each; lantern slides, 1*s.* each; packing and postage extra.

Transparencies, $6\frac{1}{4}$ inches square (Nos. 44–55 and Nos. 64 and 65), 3*s.* 6*d.* each.

Nos. 194–196 are for the stereoscope, and are not supplied as lantern slides. Transparencies, 2*s.* each; mounted aristotype prints, 1*s.* each.

Orders to be addressed to W. H. Wesley, Burlington House, London, W. In ordering prints or slides the R.A.S. Reference No. only need be quoted, but in the case of prints it should be stated whether platinotypes or aristotypes are required, and whether mounted or unmounted.

The Award of the Gold Medal.

The Council have awarded the Society's Gold Medal to Dr. P. H. Cowell for his contributions to the Lunar Theory and Gravitational Astronomy. The President will lay before the Society the grounds upon which the award has been founded.

Publications of the Society.

During the past year vol. lxx. of the *Monthly Notices* has been issued.

Obituary.

The Council regret that they have to record the loss by death of the Society's gracious Patron, His late Majesty King Edward the Seventh, and of the following Fellows and Associates during the past year:—

Fellows:—John Coles.
Henry Eichbaum.
John Ellard Gore.
Rev. H. Grattan Guinness.
Rev. Robert Harley.
John B. N. Hennessey.
Sir William Huggins.
Rev. Robert Sparke Hutchings.
Richard Coward Johnson.
Samuel Thomas Johnson.
William John Macdonnell.
Lord McLaren.
James Ebenezer Saunders.
John M. Stothard.
Sir Charles Todd.
Frederick William Watkin.

Associates:—Johann Gottfried Galle.
Giovanni Virginio Schiaparelli.

John Coles, the son of the late Charles Coles, merchant, of London, and afterwards of Tunbridge Wells, was born in London, 1833 February 18. At the age of fourteen he entered the Royal Navy, and early saw active service on the West Coast of Africa, where he distinguished himself in leading his boat's crew to the capture of a slaver. Later he served on the South American station, and at the outbreak of the Russian war he took part in the operations in the Baltic, where he lost an eye.

In 1857 Mr Coles left the Navy and went to British Columbia. After some years spent in gold mining, farming, and trading in furs, he settled at Saanich, on Vancouver Island, and was a member of the first Legislative Assembly at Victoria. A few years later he was engaged in laying cables in the Indian Ocean.

In 1877 Mr. Coles, having returned to England, was appointed Map Curator to the Royal Geographical Society; and in the following year he began the courses of instruction in Field Astronomy and Survey which have come to form one of the most useful and important branches of that Society's activity. Many explorers are indebted to him for excellent instruction in all the arts and crafts of the pioneer; and he rendered good service to geographers by editing several editions of the well-known handbook, *Hints to*

Travellers. He retired from the service of the Royal Geographical Society in 1900, but until within a few months of his death he retained the position of "Travel Editor" of the *Field*, to which he had been appointed in 1884.

Mr. Coles married, first, Mary, daughter of John Harcus, of Kirkwall; and secondly, Emma Anne, daughter of John Flintoff, of London, who, with a son and two daughters, survive him.

He was elected a Fellow 1881 January 14.

[The Council are indebted for the above particulars to the notice of Mr. Coles' life in the *Geographical Journal*, 1910 August, by Mr. E. A. Reeves.]

Henry Eichbaum was born at Cheltenham on 1834 August 28. He was educated at Christ's Hospital, and afterwards at King's College, London.

His family on the father's side had come to England for a curious reason. The men of the family were of great height, and Frederick William was determined to have them all in his famous regiment of giants—but this was not to their scholarly and peaceable taste. On his mother's side he was descended from an Austrian family, the Barons von Griesbach, of which family several members came to England with the court of George III. His great-grandfather, John Henry von Griesbach, married on 1755 January 21 Sophia Elisabeth Herschel, sister of Sir William and Caroline Herschel.

Inheriting scientific and literary tastes from both sides, Henry Eichbaum was a voluminous writer, but nearly everything he wrote was published anonymously. Only one work bears his name, *Stars and Constellations, a work for beginners*, published by Funk & Wagnall, New York, 1885.

For some years he followed the profession of civil engineer in the United States; and he married his cousin, Mary Eichbaum, of Nashville, Tennessee, who predeceased him. The last twenty years of his life were spent in England, and he died at Ventnor, 1910 August 4, leaving one son.

He was elected a Fellow 1903 December 11.

[For the above particulars of his life the Council are indebted to his ward, Miss Mary Paterson.]

John Ellard Gore was the eldest son of the Venerable John Ribton Gore, Archdeacon of Athenry, and was born in Ireland on 1845 June 1. He was educated privately and at Trinity College, Dublin, where he took the engineering degree at the Michaelmas examination in 1865, being first in his year. It does not appear that he studied Astronomy at Trinity College, but his father's house was within a few miles of Mr. Cooper's observatory at Markree, and it is possible that he learned there the tastes to which he devoted so large a part of his later life. He passed second in the open competition for the Indian Public Works Department, and served nine or ten years in India. He then

retired from the public service and settled in Dublin, where he gave himself up almost entirely to Astronomy. He was unmarried, and lived in later years alone in lodgings; a grave, quiet man, with few friends, but very much liked by all who knew him. He was a member of Council of the Royal Dublin Society, and a member of the Royal Irish Academy, to which, when failing sight compelled him to restrict his work, he presented his astronomical library.

Mr. Gore never had a telescope of any considerable size, nor anything that could be called an observatory; nevertheless he was in the forefront of British amateur astronomers. As an observer, he devoted himself to variable stars, observing chiefly with a binocular. As a computer, he calculated the orbits of a great number of binary stars. But the work by which he will be best remembered was his acute study of Herschel's theory of the system of the stars, and its comparison with later rival theories, which make his book, *The Visible Universe*, published in 1893, of real and permanent value.

He was at one time a leading member of the Liverpool Astronomical Society, but at a crisis in its affairs he and several other external members withdrew, and shortly afterwards were active in the foundation of the British Astronomical Association, of which Mr. Gore was a first Vice-President, and Director of the Variable Star section. He contributed great numbers of papers to our Society and to the Royal Irish Academy; and besides the work above mentioned, he published *Southern Stellar Objects for small Telescopes* (1877); *Planetary and Stellar Studies* (1888); *The Scenery of the Heavens* (1890); *Star Groups* (1891); *Astronomical Glossary* (1893); *The Worlds of Space* (1894); and other works, of which *The Stellar Heavens* (1903) is a very useful little treatise on sidereal astronomy.

Mr. Gore was accidentally killed in Grafton Street, Dublin, on 1910 July 18.

He was elected a Fellow of the Society 1878 March 8.

The Rev. Henry Grattan Guinness was born at Kingstown, near Dublin, in August 1835, and was the son of Capt. John Guinness, H.E.I.C.S., who had held an administrative post in India under the East India Company. He was educated at Cheltenham, Exeter, and at New College, London, and in 1856 was ordained as an undenominational evangelist.

Related collaterally to the great Irish orator, Henry Grattan, after whom he was named, he possessed in a high degree the same power of swaying popular assemblies, and as a young man his reputation and success as a preacher stood very high. Later on in life he devoted himself principally to the training of missionaries, especially for work in regions yet unvisited, and Harley College, Bow, was established by him for men, and Doric Lodge for women.

He took a deep interest in the progress of science, especially in that of Astronomy, for the study of which he set up an equatorial, carrying a 12-inch reflector, at his home at Curbar, in Derbyshire,

near Sheffield. He was an able and voluminous writer, chiefly on religious subjects. The subject of ancient chronology had a great attraction for him, and received much attention in several of his books, whilst, as an appendix to his book *Creation centred in Christ*, he published a catalogue of the times of all the new moons from B.C. 1622 to A.D. 1934, together with several useful chronological tables.

Dr. Grattan Guinness was twice married; first, in 1860, to Miss Fanny Fitzgerald, by whom he had several children, of whom three survive. Mrs. Guinness died in 1898, and some years later Dr. Guinness married Miss Grace Hurditch. He leaves two sons by this second marriage. He died at Bath on Tuesday, June 21, in the seventy-fifth year of his age.

He was elected a Fellow of the Society 1891 January 9.

E. W. M.

The Reverend Robert Harley was born at Liverpool on 1828 January 23, the third son of the late Rev. Robert Harley. He developed great mathematical ability at an early age, and in 1846 he brought himself to the notice of mathematicians by answering a question relating to the general quintic equation which Sir James Cockle had propounded in the *Lady's and Gentleman's Diary*. After studying for the Congregational ministry at Airedale College, Bradford, Mr. Harley became minister at Brighouse, where he remained till 1868, and where he did the distinguished work in pure mathematics which brought him the Fellowship of the Royal Society in 1863.

In 1868 Mr. Harley removed to Leicester, where he took a prominent part in public affairs as President of the Leicester Literary and Philosophical Society, member of the Museum Committee, and Honorary Curator. In 1872 he was appointed Vice-Master of Mill Hill School, where he remained till 1881; in 1882 he became Principal of Huddersfield College; and in 1886 he took charge of a Congregational church at Oxford, where he received from the University the honorary degree of M.A. In 1890 he went for a year to Australia, returned to Halifax, and finally retired from active work in 1895.

He was interested in Astronomy, and delivered many lectures on it; but his scientific work lay almost entirely in the regions of pure mathematics and symbolic logic, on which he published many papers. He had served on the Council of the London Mathematical Society, and as Secretary and Vice-President of Section A of the British Association.

At his death, which took place on 1910 July 26, he was the Senior Fellow of the Society, to which he was elected 1854 January 13.

John Bobanau Nickterlien Hennessey was born in 1829, August 1st, at Fatehgarh; he joined the Trigonometrical Survey of India under Sir Andrew Waugh, R.E., in 1844, and was promoted

to the Senior Division in 1854. During the Mutiny he saw five months' service under arms as a volunteer in and around the hill station of Mussoorie.

In 1863 he came to England on long leave, entered Jesus College, Cambridge, and studied mathematics. On his return to India in 1865 he resumed charge of the Computing Office of the Trigonometrical Survey at Dehra Dûn, N.W.P., and took up with remarkable energy the organisation and supervision of the many varied services connected with the office. He commenced the printing of all the principal Angles, which, except the Great Arc Series, published by Sir G. Everest, had hitherto been only in manuscript. He also introduced photozincography for the cheap and rapid reproduction of original maps, having learnt the process at the Ordnance Survey Office at Southampton while on leave, and sheets of the Topographical Surveys were rapidly reproduced for publication. The process was also adopted in the Surveyor-General's Office at Calcutta for the cheap and accurate reproduction of maps and plans, not only of the Indian Surveys, but also of miscellaneous drawings of all kinds, capable of photographic reproduction, for the Public Works, Military and other Departments of the Indian Government.

In 1867 he was deputed by the Surveyor-General, Colonel J. T. Walker, R.E., C.B., to take his place in the measurement of the New Bangalore Base. After this he assisted the Surveyor-General in the verification of the standards of length, and also in revising and extending the "Auxiliary Tables," for facilitating the calculations of the Survey Department. About the same time he volunteered to take charge of the Meteorological Observations at Mussoorie and Dehra Dûn, and took considerable interest in the work till he retired. His first communication to the Royal Society was a note "On a supposed Connexion between the amount of Rainfall and the Changes in the Moon" (*Proc. R.S.*, xvi., 1868). Another meteorological paper was a "Note on the Periodicity of Rainfall" (*Proc. R.S.*, xxii., 1874). In 1869 he commenced a series of actinometrical and spectroscopic investigations at the instance of Professor Stokes, Balfour Stewart, and others. The results of his actinometrical observations, communicated to the Royal Society, were published in *Proc. R.S.*, xix., 1871; xxxi., 1881; and xxxiv., 1883. His spectroscopic observations were published in the following papers:—"On the Atmospheric Lines of the Solar Spectrum, 1870," *Proc. R.S.*, xix., 1871; "Note on the Displacement of the Solar Spectrum, 1873," *Proc. R.S.*, xxii., 1873; "On White Lines in the Solar Spectrum, 1873," *Proc. R.S.*, xxii., 1873–4, and xxiii., 1875; "On the Atmospheric Lines of the Solar Spectrum, illustrated by a map on Kirchhoff's scale, 1874," *Proc. R.S.*, xxiii., 1875, and *Phil. Trans. R.S.*, clxv., 1876.

In 1871 he was deputed to assist Colonel J. F. Tennant, R.E., in observing the Total Solar Eclipse on 5th April 1871 at Dodabetta, near Ootacamund, and took general charge of the photographic observations. In 1874 he observed the Transit of Venus at

Mussoorie on December 9, and published his observations in two notes in *Proc. R.S.*, xxiii., 1875, and a further one in xxvii., 1876. From May 1878 he superintended the working of the daily photoheliographic observations of the Sun's surface, on behalf of the Solar Physics Committee, at first with a small photoheliograph giving 4-inch pictures, and afterwards, in 1882, he arranged for the building of a suitable observatory for working the large photoheliograph giving 8-inch pictures on 12-inch plates, and the setting up of this instrument seems to have been his final work.

In May 1881 observations with earth thermometers were started by him at Dehra Dûn under some difficulties, involving the digging a series of holes 6 to 8 inches square and from 1 foot to 25 feet 6 inches deep in a rocky soil. These observations gave some very interesting results, which are recorded in the Indian Survey Reports for 1880–81 and subsequent years.

The above will show the varied nature of Mr. Hennessey's miscellaneous duties apart from the arduous work of the Computing Office, and his zeal in furthering scientific inquiry.

In 1883 he succeeded to the Administration of the Trigonometrical Branch as Officiating Deputy Surveyor-General, and was confirmed in the appointment in January 1884. He retired after forty years' service, on October 1, 1884, and was awarded a special superannuation pension in recognition of his high scientific acquirements and long and faithful services.

The following extract from the preface to volume i. of the "Account of the Operations of the Great Trigonometrical Survey of India, 1870," shows the very high opinion the Surveyor-General, Colonel J. T. Walker, R.E., had of his services:—"To the Officers of the G. T. Survey who have had a share in the operations discussed in this volume, I am most indebted to J. B. N. Hennessey, Esquire, who has for many years past been in charge of the Computing Office at the Headquarters of the Department, and whose constant self-devotion to his work and accurate and conscientious discharge of his duties I cannot praise too highly. He has either supervised or taken a principal share in the whole of the comparisons of standards which have been made in India since the year 1866 and are here described. He has also re-investigated the factor of expansion of the principal standards of length of this Survey, his account of which is given in Appendix No. 6, and he has superintended the reduction of most of the ten base lines of which the details are given in this volume, and has prepared the whole of them for publication."

Upon him devolved the training of young officers and others in the work of the Survey, and the writer can only say of him that he was most precise, methodical, and thorough in his teaching, pleasant and kind in his manner.

In 1860 he was elected a Fellow of the Royal Geographical Society. In 1875 the Royal Society elected him a Fellow, and in 1876 the University of Cambridge conferred on him the honorary degree of M.A. In 1885 he was made a Companion

of the Indian Empire. Since 1884 he had lived in West Dulwich, where he died on 1910 May 23, in his eighty-second year, leaving a widow and only daughter.

He was elected a Fellow of the Society on 1864 February 12.

J. W.

William Huggins, Knight Commander of the Bath, was born in 1824 February 7. He was educated at the City of London School and by private teachers. In his earlier years he was much tempted to devote himself to microscopical research in connection with physiology, and he made himself familiar with the methods of chemical and physical research. In 1852 he joined the Microscopical Society, and the whole of his life's work shows how strongly his mind was attracted to the application of micrometrical methods to the elucidation of large problems. After some hesitation he decided to give his chief attention to Observational Astronomy. In 1856 he built a convenient observatory close to his house on Tulse Hill, and described it in a very brief note (*M.N.*, xvii. 175, 1856 May 9), the first of his many communications to our Society. The equipment consisted of an equatorial by Dollond, 5 inches aperture; a transit-circle by Jones, $3\frac{1}{4}$ inches aperture, with a circle 18 inches in diameter, divided on silver to 5′, and a clock by Arnold. His earliest published observations related to occultations at the limb of the Moon, of Jupiter (*M.N.*, xvii. 2), of Spica (*M.N.* xvii. 203). In 1858 he purchased from Mr. Dawes an object-glass by Alvan Clark, of 8 inches diameter, and had it mounted equatorially, and provided with a clock motion by Thomas Cooke of York. He seems to have begun work with the new equatorial by studying the planets, for he published notes about Jupiter and the disappearance of Saturn's ring. The change in the forms which the belts and spots on the planet Jupiter assume at different epochs struck his attention; and several of his drawings, contrasting the comparatively inactive state of the planet during 1858–9 with the strongly defined and actively changing dark belts seen in the year 1862, were exhibited at the June meeting of the Society in 1862. Several of these drawings were published for the first time in the edition of his collected papers in 1909.

He became dissatisfied, as he has recorded in the article of personal retrospect which he contributed to the *Nineteenth Century* for June 1897, with the routine character of ordinary astronomical work, and sought about for the possibility of research upon the heavens in a new direction or by new methods. "It was just at this time that the news came of Kirchhoff's great discovery [1859] of the true nature and chemical constitution of the Sun, from his interpretation of the Fraunhofer lines. This news came to me like the coming upon a spring of water in a dry and thirsty land. Here at last presented itself the very order of work for which in an indefinite way I was looking—namely, to extend his novel methods of research upon the Sun to the other heavenly bodies."

It was on January 15, 1862, that the scientific partnership began between William Huggins and William Allen Miller, Professor of Chemistry at King's College, London. They were already friends and neighbours; and on the evening of the date just mentioned, Miller had been repeating before the Pharmaceutical Society of London a lecture on Spectrum Analysis which he had given in the previous year before the British Association at Manchester, at the time when Kirchhoff's researches had made the subject unusually popular. "One part of this lecture" (as we learn from the obituary notice of W. A. Miller, *Proc. R.S.*, xix. p. xxii.) "was directed to an historical review of that remarkable branch of chemico-physical research; and so little attention had been paid to this part of the subject that when a large audience were collected to hear, as they supposed, an account of Kirchhoff's discoveries, they were not a little surprised to find Kirchhoff occupying the end of a long series of illustrious names, from Newton in 1701 to Wollaston in 1802 and Fraunhofer in 1815; whilst the various other names were arranged after the fashion of a genealogical tree, under the four heads of (1) Cosmical Lines, (2) Absorption Bands, (3) Bright Lines produced by the Electric Spark, and (4) Coloured Flames, the four branches uniting in the names of Kirchhoff and Bunsen in 1860." The writer has not been able to get access to the *Pharmaceutical Journal*, February 1862, where Dr. Miller's lecture was printed, but fortunately it is possible to reproduce the table above referred to from our own *Monthly Notices* (xxvii. 166).

Chronological Table of the Writers who have taken the principal steps leading to Spectrum Analysis.

(From Dr. W. A. Miller's Lecture. *Pharmaceutical Journal*, 1862 Feb.)

Newton, 1701.
Wollaston, 1802.
Fraunhofer, 1815.

Cosmical Lines of Solar and Stellar Spectra.		Absorption Bands.		Bright Lines of Electric Light.		Coloured Flames.	
Brewster	1832	Brewster	1832	Wheatstone	1835	Brewster	1822
E. Becquerel	1842	W. H. Miller and Daniell	1833	Foucault	1839	Herschel	1822
Draper	1842			Masson	1851–55	Fox Talbot	1826
Stokes	1852	W. A. Miller	1845	Alter	1854–55	1833 and	1834
Brewster and Gladstone	1860			Secchi	1855	W. A. Miller	1845
				Plücker	1858–60	Swan	1857
				Van der Willigen	1859		

Balfour Stewart 1858 (Law of Exchanges).
Kirchhoff 1859.
Kirchhoff and Bunsen 1860.

After the lecture the two friends returned home together to Tulse Hill, and on the way Huggins spoke of the attempt he was about to make to apply Kirchhoff's methods to the stars, and asked Miller to join in the investigation. Huggins has told, in the article in the *Nineteenth Century* already referred to, how Miller, whose experience in chemical spectroscopy was already very great, at first

hesitated as to the probability of success; but the partnership was initiated and continued for two years, resulting in a splendid harvest of conclusions. The work had begun with the designing and construction of a suitable star-spectroscope, and the collection of the accessory chemico-physical apparatus; it had included the mapping of the spectra of twenty-six of the terrestrial elements (this work was carried out by Huggins single-handed, and published in the *Philosophical Transactions*, vol. cliv., in 1863), and had finished with the conclusion that "the stars, while differing the one from the other in the kinds of matter of which they consist, are all constructed upon the same plan as our Sun, and are composed of matter identical at least in part with the materials of our system." (*Phil. Trans. R.S.*, 1864, p. 434.) This paper was communicated to the Royal Society in April 1864; after that time Dr. Miller had not sufficient leisure to continue the work, and Huggins pursued his researches alone, except on one or two occasions, such as the outburst of the New Star in Corona Borealis in 1866, when Miller again joined in the observatory work (*M.N.*, xxvi. 275). Recognition was at once forthcoming, not only of the resourcefulness of the investigators and the refined delicacy of their observations, but also of the importance and deep interest of the results obtained. Professor Pritchard, in presenting the gold medal of our Society in 1867 to the two collaborators "for their conjoint and important researches in Astronomical Physics," summed up the situation in the following words:—"I have made it my endeavour to remind you, in the first place, how the progress which Astronomy has made towards completeness in most of her ancient departments naturally suggests the commencement of researches in some new direction. In the second place, I have intimated that, owing to the rapid advance of the experimental sciences, the new direction would naturally be rather towards the Physics than the Dynamics of Astronomy; towards inquiries into the material constitution of the heavenly bodies rather than into the laws for the relations of their motion. Lastly, I have endeavoured to lay before you how rich, and varied, and early have been the fruits which your Medallists have gathered from the new grounds of research which they have cultivated with so much success."

The award of the Medal on that occasion had involved an alteration of the bye-laws to make it possible to include Professor Miller in the award. The President expressed gratification that the Society had assented to the course proposed by their Council; for they conceived that "a rare and happy opportunity had arisen for the Astronomical Society to pay the graceful tribute of their hearty sympathy with faithful labourers in fields of science different from their own."

The Royal Society awarded a Royal Medal in 1866 to William Huggins "for his Researches on the Spectra of some of the chemical elements, and on the Spectra of certain of the heavenly bodies; and especially for his Researches on the spectra of the Nebulæ." The President, General Sabine, in presenting the Medal, explained that,

of the researches referred to in the award, those on the stellar spectra "were made by Mr. Huggins conjointly with our highly valued Treasurer and Senior Vice-President, Dr. William Allen Miller," and that the Council were debarred by the position of the latter as one of the officers from considering his claims to share in the honours which the Society could bestow. We can well understand how Miller would have supported Huggins's claims to receive the distinction. The work on the Nebulæ which is specially mentioned in the award was completed in the first six months after Miller had had to withdraw from collaboration; and Huggins had, moreover, succeeded not only in analysing the light of the small Comet No. 1 of 1866, but also in studying the spectrum of a new star. We read with a curious interest the personal words addressed to the recipient of the Medal by the President:—"You are at an age at which you may reasonably indulge in the prospect of having a long career before you; yet, however long, it will scarcely exhaust the noble field of research which you have opened for yourself, and which is one in which you are quite sure to be accompanied by the sympathy of men of science throughout the world."

Huggins's discovery of the peculiar nature of the spectrum of many of the nebulæ roused even greater interest than his studies of stellar spectra. The nature of a nebula, and even the existence of a nebula, as we now understand the term, had for years been a much controverted question. It was often supposed to be nothing but a cluster of stars so remote from the Earth that the individual stars could not be discerned as such. Sir William Herschel himself had, by a series of observations with gradually increased telescopic power, convinced himself that many of Messier's "nébuleuses sans étoiles" were resolvable into clusters of stars (1784), but he had also discovered, with his increased power, many new objects which he, in turn, was unable to resolve. In a process of reasoning applied in an attempt to arrange these observed objects in an order of development, he committed himself to the view that distance alone altered the appearance of the bodies, and that in reality they were all "of a starry nature." In 1791 he revised his views, the starting point being an observation of a star in Taurus of about the 8th magnitude, surrounded with a faintly luminous atmosphere of considerable extent. The situation seemed, he said, to require just such a new kind of object as this star afforded to set us right again, and with this suggestion he once more started on a new line of thought, with beautifully simple and plausible reasoning. It was then that he first committed himself to the idea of shining fluid and luminous matter, which was formally developed in 1811. The question was re-opened by the observations which Lord Rosse was able to make with his 6-foot reflector in 1846. Nicol, in his *Architecture of the Heavens*, thus reports Lord Rosse's verdict in favour of the starry nature of the nebula in Orion: "and thus doubt and speculation disappeared from this great subject for ever."

The year 1864 saw the publication of Sir John Herschel's

General Catalogue of Nebulæ and Clusters. Without a word of reference to the controversy, it went forth as a business-like catalogue of the places and appearance of 5079 celestial objects, for the use and guidance of astronomers. The same year saw the publication of Huggins's discovery of the gaseous nature of eight planetary nebulæ, proving that they could no longer be regarded "as aggregations of suns after the order to which our Sun and the fixed stars belong," and that we must regard them "as enormous masses of luminous gas or vapour." This same memoir contained also record of observations of the spectra of several clusters of stars; and the essential difference between the spectroscopic characteristics of a planetary nebula and a cluster of stars was well illustrated. In a lecture which Huggins delivered at the Royal Institution in May 1865, he gave several instances of that thoughtful penetration which was characteristic of him. Foreseeing that many would jump to the conclusion that Herschel's views were wholly supported by the new observations, he pointed out that "the uniformity and extreme simplicity of the spectra of all these nebulæ oppose the opinion that this gaseous matter represents the nebulous fluid suggested by Sir William Herschel, out of which stars are elaborated by a process of subsidence and condensation. In such a primordial fluid all the elements entering into the composition of the stars should be found. If that existed in these nebulæ, the spectra of their light would be as crowded with bright lines as the stellar spectra are with dark lines." And again: "If the observations of Lord Rosse, Professor Bond, and others are accepted in favour of the partial resolution of the annular nebula in Lyra and the great nebula in Orion into discrete bright points, these nebulæ must be regarded not as simple masses of gas, but as systems formed by the aggregation of gaseous masses."

In reading the original paper in the *Philosophical Transactions* for 1864, one cannot but be struck by the restraint of the writer, as if he himself were in a measure awe-stricken by his discovery. And yet the spirit of the true investigator discloses itself when he records the fact that whilst nitrogen alone of all the thirty chemical elements the spectra of which he had measured exhibits a strong line near the bright line of the nebulæ, yet other lines in the spectrum of nitrogen, bright enough, as one would think to be visible in the nebulæ, are not seen. He concludes, with a bold speculation, that the occurrence of this one line only in the nebulæ may indicate a form of matter more elementary than nitrogen, and as yet unknown to our analysis.

From that time onwards the rôles of student, of pioneer, and of leader were blended in Huggins without a break up to the time of his death in his eighty-seventh year. He had, only a few months before his death, completed the task of drawing together the threads of his life's work by collecting and editing his scientific papers. He had the splendid satisfaction of feeling that these records, thrown off from year to year through five decades, held their position with hardly more than twenty editorial footnotes,

as lasting steps of progress in the subject of his choice. In hardly a single branch of it could an historical summary now be made without dwelling on some of his work as of prime importance in the development.

From the outset he realised the need of minute accuracy in obtaining the exact positions of the lines in the spectra investigated. He saw that it could best be achieved by direct comparisons of the spectra of metals and other elements with the spectra of the stars and the Sun. This wisdom constituted him a recognised authority from the first. His earliest observations with Miller, of the apparent coincidences of bright terrestrial lines with dark lines in the spectrum of a star, furnished the means of deciding without reserve the presence of certain elements in the stars, to wit, in the cases of substances possessing spectra of marked characteristics such as peculiar grouping of lines, as for instance, in hydrogen, iron, sodium, magnesium. This research could be and was achieved with the small power of the stellar spectroscope attached to the 8-inch achromatic telescope. But Huggins was not content with this except as a first step. He sought for signs of minute defect of coincidence as the means whereby information could be gained about the movement of the stars; and after failure with the power of these prisms in 1866, he achieved success in 1867 with a spectroscope in which he could use the effective power of $4\frac{1}{2}$ or $6\frac{1}{2}$ prisms of angle 60°. Thus it came about that in 1868, the year in which Secchi had announced his inability to find signs of motion, and published his conclusion that the stars examined were not moving with appreciable velocities, Huggins announced that he had measured the velocity of Sirius, and that it was receding from the Sun with a velocity of 29 miles per second. His successful observations must have been made in November 1867, for the correcting term which he had used to allow for the star-ward component of the Earth's orbital velocity had a magnitude appropriate to that month. In the paper (*Phil. Trans.*, 1868) in which he published his result for Sirius, he announced that he had made similar comparisons on α Canis Minoris, Castor, Betelgeux, and Aldebaran, but reserved the results, wishing to submit these objects to re-examination. In correcting the proofs of his paper he was able to add a note dated October 1868, to the effect that an apparatus in many respects superior to the one described had been since constructed. In 1872 he gave (*Proc. R.S.*, xx. 379) the results of his further researches, summarising them in two tables, the one containing data for 19 stars moving from the Sun, the others containing data for 11 stars approaching the Sun. In editing this paper for reprinting in his collected papers he added the following note:—

"Though my original observations for the purpose of detecting motion in the line of sight were undertaken with a full understanding of the many careful precautions which are necessary to avoid instrumental and other sources of possible error, as my papers show, yet it was a task almost beyond what was possible to accomplish, without some uncertain results, with my instrumental

means, and by my observations. It was therefore not improbable that some of the numerical velocities might not be confirmed by later observations.

"In 1880, with the introduction of the dry plate (which I was the first to use astronomically), I resumed successfully my early attempts in 1862 to photograph the spectra of the stars, and made preliminary trials of photographing star spectra on the same plate together with terrestrial spectra for the determination of motion in the line of sight.

"It was only at a later date, in 1888, after dry plates of more adequate sensitiveness had been provided by photographers, that Vogel, at Potsdam, showed that by means of photography the spectroscopic method of determining celestial motions in the line of sight could well come within the range of the ordinary routine work of an observatory."

The present notice has been limited to a few details concerning the circumstances of Sir William Huggins's earlier work. The following paragraphs are reprinted, with slight alterations, from a notice that appeared in *Science Progress* for October 1910. Those years in the late sixties must have been strenuous years for Huggins. He gave his services as Secretary to our Society in 1867, and continued them for seven years; he served on the Council of the Royal Society in 1866–68 and 1869–71. And we know that he was engaged in these years on two researches, each of which was no less than an actual foundation-stone on which the vast constructions of the new astronomy lie. In one of them, namely, the development of the method of viewing solar prominences, he was hard pressed by other workers who were engaged in the study of the phenomena of the eclipsed Sun. In the other, namely, the establishment of the possibility of determining, by measurements of position of the highest refinement in stellar spectra, the velocity of approach or recession of the body from which the light comes, nothing short of the inextinguishable faith of Huggins could have carried the work through to a triumphant conclusion. It has been well said of him that with an enthusiastic heart he combined a cool head.

Only those who have had experience of work even with the more powerful instruments of modern days, built up upon the experience which Huggins had to gain for himself, can appreciate fully the skill and patience and delicacy of hand and eye which enabled him to make these early conquests. Not that the value of his investigations was unrecognised at the time. On the contrary, the Royal Society put at his disposal the Oliveira bequest which had come into their hands for the construction of a large telescope. And so it came about that just at the end of the period in which the limited appliances had been so well utilised, and when they began to be inadequate, Huggins was able to improve his instrumental equipment enormously. The dome was enlarged, its diameter being made 18 feet instead of 12 feet; and in place of the 8-inch object-glass he was provided with a 15-inch object-glass

of the short focal length of 15 feet, and also a Cassegrain mirror, of aperture 18 inches and of focal length 11 feet. Each of them was mounted in a suitable tube, and they were arranged so that either one or the other, according to the needs of the observer, could be attached to the equatorial mounting. The work of construction was carried out by Sir Howard Grubb in 1869–70. It will give some idea of the activity in the new Observatory if a paragraph be devoted to summarising the modes in which the instrumental equipment was utilised for various researches.

During five years, 1870–75, the achromatic telescope was used in determination of the velocity of stars in the line of sight, by means of visual observations. The spectra of Uranus and Neptune and of various nebulæ were studied, and some time was given to observations of Coggia's Comet. The rotation of the Sun was also investigated. In 1876, which we may recall as the year following Dr. Huggins's marriage with Miss Margaret Murray, the reflector was mounted in place of the achromatic telescope. During the next six years, 1876–82, the reflector was used in the study of planetary spectra, and, after preliminary work had been carried out to gain experience in photographing spectra, the spectroscope with a single prism of Iceland spar was constructed and got into adjustment for obtaining by photography the ultra-violet spectra of the stars and nebulæ. The Comets of 1881 and 1882 demanded attention; and it may be surmised that it was the unexpected appearance of these bodies which led Huggins to have a change made in the equatorial mounting, whereby it should be possible to keep both reflector and refractor permanently in adjustment and ready for use in any emergency. These telescopes had previously been interchangeable on the mounting, either of them being counterpoised by a dead weight at the end of the declination axis. But in 1883 the dead counterpoise was abolished, and a new double declination axis was made, carrying the reflector at one end and the refractor at the other, one thus serving as a counterpoise to the other, and each being movable in declination independently of the other. With the new arrangement it was easy to pass from investigation of ultra-violet spectra with the reflector to visual observations of Nova Aurigæ with the refractor. New spectroscopes were designed and constructed for each; and thus either a dense glass prism or a grating was available with the one, whilst a spectroscope with two prisms of Iceland spar was arranged for the other.

This brief summary of the development of his instrumental requirements serves to show the activity with which Huggins moved ahead in his researches. It is curiously similar to the development which marked the advance a generation later at all points, with one large difference—namely, that the earlier advance must be regarded as due mainly to the pioneering efforts of one man, whilst the later gained its impetus from the confidence inspired by those efforts in a widespread movement of collaboration.

The results and records of Huggins's life's work are contained

in two volumes, bearing the title *Publications of Sir William Huggins's Observatory.* The first volume, *Atlas of Representative Stellar Spectra*, was published in 1899, and contains "the later original work of the Observatory which had not been previously published elsewhere; and in addition, it offers theoretical discussions on this newer work in connection with the earlier observations contained in the separate papers." The second volume contains a reprint of the published papers recording the work done in the Observatory since its foundation in 1856.

Many were the marks of distinction that were offered to Sir William Huggins in recognition of his scientific achievements. The Royal Society made him one of their number in 1865, and afterwards bestowed on him three of the Medals which it is their privilege to award—a Royal Medal in 1866, the Rumford in 1880, and the Copley in 1898. He received the Gold Medal of the Royal Astronomical Society in 1867 jointly with Professor Miller, and again in 1885 for his researches on velocity in the line of sight and on the photographic spectra of the stars and comets. The Paris Academy of Sciences awarded him the Lalande Prize in 1872, and elected him to their ranks as a Corresponding Member in 1874. Another honour came to him from France in 1888, when he received the Prix Janssen of the Institute; and yet another from America in 1901, when he received the Draper Gold Medal from the National Academy of Sciences of Washington. The University of Cambridge gave him the honorary degree of LL.D. in 1870, and a few months later he received the degree of D.C.L. from the University of Oxford. He also held honorary degrees from various other universities, both at home and abroad; many foreign learned societies enrolled him as an Honorary Member.

He rendered valued service to many societies. From 1876 to 1878 he was President of the Royal Astronomical Society; he was for seven years one of the Secretaries and for thirty years the Foreign Secretary of that Society. In 1891 he served as President of the British Association at its Cardiff meeting. After being three times Vice-President, he was chosen in 1900 to succeed Lord Lister as President of the Royal Society, and filled the office for five years with marked dignity and distinction. In his seventy-fourth year, on the occasion of the Diamond Jubilee of Queen Victoria, he was made a Knight Commander of the Bath, and four years later (1901) he was one of the group of twelve who first received the Order of Merit established in that year.

Sir William Huggins married in 1875 Miss Margaret Lindsay Murray, the daughter of Mr. John Murray, of Dublin, a lady in whom he found an able and enthusiastic collaborator and assistant. Her name appears as joint author with his own on many of the scientific papers published by him since that date. Sir William died on 1910 May 12 in his eighty-seventh year. An admirable portrait of him in his eighty-first year was painted by the Hon. John Collier; it hangs in the rooms of the Royal Society. It also

appears in photogravure, together with a portrait of Lady Huggins, in the opening pages of the volume of his collected scientific papers.

He was elected a Fellow of the Society 1854 April 12.

H. F. N.

The Reverend Canon Robert Sparke Hutchings was born, 1819 December 18, on the island of Pulo, Penang, East Indies, where his father was chaplain, holding at the same time the living of Dittisham, Devon. He was educated at the Clergy Orphan School in London, and was an exhibitioner of Christ Church, Oxford. After taking his degree in 1845 he was ordained to the curacy of Kingsteignton, South Devon, and in the same year he married Frances, only surviving child of the late Charles Philip Hodson, of Stainley Hall, Yorks.

In 1850 he was appointed Vicar of Monkton Wyld, Dorset, and in 1865 was made Vicar of Alderbury, near Salisbury; this living he held until his death, having been made an Honorary Canon of Salisbury in 1876. He was greatly interested in Astronomy, and owned several good instruments.

His wife predeceased him in 1896, a year after the celebration of their golden wedding. He died 1910 November 6, leaving two sons and two daughters.

He was elected a Fellow on 1886 December 10.

Richard Coward Johnson was born in Liverpool 1840 May, of an old Lancashire family, and was educated locally. In early life he travelled much, and was for some time actively engaged in the exploration of Moab.

His interest in astronomy was lifelong. He was quick to recognise the great opportunity that the silver-on-glass reflector gave to the amateur astronomer, and from time to time he contributed to the Society results of his work in celestial photography. His last paper was "On observations of Comet Morehouse, 1908" [*M.N.*, lxix. p. 216]. He helped to form the Liverpool Astronomical Society, and was elected its President in 1882. He was a well-known member of the Liverpool Literary and Philosophical Society, and was one of its Vice-Presidents for many years.

A mathematician of no mean order, an able mechanic, and a good all-round astronomer, whose time and apparatus were always at the service of his fellow-workers, Mr. Johnson was a delightful companion, and he will be long regretted by many scientific friends.

He was elected a Fellow 1876 January 14. F. W. L.

William John Macdonnell was born, 1842 November 28, in Dublin, and at a very early age went with his parents to Sydney. His education was commenced at a private school in Balmain, a suburb of Sydney, and at the age of about sixteen he was sent with his younger brother to finish his education in Germany, On his return to Sydney he at once took up the study of Astronomy.

With a sound mathematical knowledge and untiring zeal as an observer, he was recognised by the late Mr. Russell, then Director of the Sydney Observatory, as a most desirable addition to the volunteer observing staff for the transits of Venus in 1874 and 1882. Mr. Macdonnell accompanied one of the former expeditions to Eden, under the leadership of Mr. Scott (formerly Director of the Sydney Observatory), and one of the latter expeditions was left largely under his control at Port Macquarie. Mr. Macdonnell settled in Port Macquarie for many years, having charge, as manager, of a bank there. He imported a 6-inch equatorial refractor from Grubb of Dublin, which, with a transit instrument and clock, were housed in a locally made observatory. Later on he resigned his situation at the bank and went to Sydney, where he went into business as legal manager, and in this capacity he was well known in business and mining circles. He resided at Mosman, near Sydney, where he built another observatory, in which was placed a $4\frac{3}{4}$-inch refractor by Parkes of Birmingham. Mr. Macdonnell was an active member of the New South Wales Branch of the British Astronomical Association, and was President of it for two years. He held afterwards the offices of Hon. Secretary and Hon. Treasurer, and it is recognised that the success of the Branch has largely been the outcome of his active work in connection with it. Mr. Macdonnell possessed a large and valuable library of books, chiefly in connection with Astronomy, and this, as well as his instruments, were freely at the disposal of his friends for reference and use. His kind and sympathetic nature, and the interest he took in the young amateur, endeared him to many who, through his influence and example, were induced to take an active interest in the science which he had so much at heart. He died on September 22, 1910, at the age of sixty-eight, and leaves a widow.

Mr. Macdonnell contributed to the *Monthly Notices* an account of his observations of the transit of Mercury, 1891 May 10.

He was elected a Fellow on 1873 January 10; he ceased to be a Fellow in 1899, and was again elected 1910 February 11.

[The Council are indebted for this notice to his friend Mr. G. D. Hirst, of Sydney.]

John McLaren was born at Edinburgh in 1831 April 17, the eldest son of the late Duncan McLaren. After graduating at Edinburgh University he was called to the bar, or rather, in Scottish phrase, he passed advocate, in 1856. He wrote several legal treatises, some of which are still highly valued for their clear, precise language and luminous treatment of principles. In politics a Liberal, he was returned to Parliament in 1880, and was created Lord Advocate by Mr. Gladstone. His political experiences were not untroubled. At the resulting bye-election he lost his seat, and was without a seat in the Commons for nearly a year, when he was returned for Edinburgh. His office was then subordinate to that of Home Secretary; some friction

developed between Mr. McLaren and Sir William Harcourt, and ultimately the difficulty was solved by his promotion to the Scottish bench. He was thoroughly successful in his new capacity. He made a capital Judge, accurate, precise, fair-minded, and patient, and his death is a loss to the bench.

Lord McLaren's scientific interests were constant throughout his life, and active when promotion to the bench gave him leisure. He served as Vice-President of the Royal Society of Edinburgh for many years, and as a member of its Council continuously from 1883 to 1909, where his advice in matters of business and his skill in drafting documents were of high service. He also contributed several papers to its *Proceedings* and *Transactions* which show considerable mathematical skill. Among these may be mentioned *Tables of Differential Refraction*, and one on *Aplanatic Lenses*. He was a keen astronomer, and acquired, among other telescopes, the 4 inch heliometer with which Sir David Gill made his observations of Mars at Ascension. With Lord Crawford, Professor Copeland, Professor Tait, and an official of the Exchequer, he had charge of the arrangements for establishing the Royal Observatory at Blackford Hill. He continued to take a lively interest in its working, and lent his heliometer to Dr. J. Halm for observations of the solar rotation by the method of displacement of the spectral lines. He was also a Director of Ben Nevis Observatory. His own university conferred the degree of LL.D. upon him in 1882, and Glasgow the same degree in the following year. He leaves a widow and three children.

He was elected a Fellow of the Society 1884 December 12.

R. A. S.

Sir Charles Todd was born at Islington, England, on 1826 July 7, and was educated at Greenwich.

On 1841 December 6 he entered the service of the Royal Observatory at Greenwich as Astronomical Computer.

In 1847 he was appointed Assistant Astronomer at the Cambridge Observatory, under the Rev. James Challis. While at Cambridge he made a galvanic determination of the difference of longitude between Greenwich and Cambridge. He was also in charge of the Northumberland telescope, and was justly proud of the fact that with it he was the first in England to take a daguerreotype photograph of the Moon. He was also, in 1846, one of the earliest observers of the newly discovered planet Neptune.

But the Astronomer-Royal (Airy), recognising his exceptional abilities, was anxious to have him back; in 1854 he was offered an appointment as Assistant at Greenwich, and placed in charge of the new galvanic department. When in charge of that department he was responsible for the transmission of time signals throughout England and the dropping of the time-balls.

In 1855 he had occasion to visit Deal, some trouble having occurred in the dropping of the time-ball, and on his way back to headquarters he received a letter from Mr. Airy offering him, on

behalf of the Colonial Office, the position of Superintendent of Telegraphs and Government Astronomer in South Australia. This offer he accepted, and before leaving England he married Miss Alice Gillam Bell, of Cambridge. On his wedding-day he said that he was going out to Australia with the hope of being instrumental in bringing England and Australia into telegraphic communication.

His earliest achievements in his new home were to connect the Australian capitals, Adelaide, Melbourne, and Sydney, by telegraph. On the completion of the direct line from Adelaide to Sydney in 1868 he utilised it for determining the 141st meridian, thus fixing the eastern boundary of South Australia. Longitude signals were exchanged with Ellery of Melbourne and Smalley of Sydney Observatory, the results showing that the boundary between South Australia and Victoria as formerly determined was two and a quarter miles too far westward. Thus arose the "Disputed Boundary" case, which is at the present time before the High Court of Australia for settlement. The determination of Australian longitudes made in 1883 at the instance of the Royal Society and Royal Astronomical Society in connection with the transit of Venus observations of 1882 December, confirmed the 1868 boundary determination.

But the work with which the name of Sir Charles Todd will always be most closely associated was the construction of the transcontinental telegraph line between Adelaide and Port Darwin, which constituted the last great link in the telegraphic chain connecting Australia with the old world. Two thousand miles of unknown country had to be spanned, and all the poles and other material had to be conveyed by waggons or camels. The successful journey of the explorers M'Kinlay and Stuart across the continent had paved the way for this enterprise. The other colonies were invited to share in it, but declined, and South Australia went ahead with the work alone. It was commenced in 1870 and completed in 1872. On August 22 of that year, at Central Mount Stuart, in the very centre of the Australian continent, Sir Charles had the satisfaction of completing the line of communication between Adelaide and Port Darwin, and of receiving on his little pocket relay messages of congratulation from the Governor and citizens at Adelaide. The cable between Port Darwin and Java, however, was broken down, and it was not restored till October 21, when communication was established with England. On November 15 banquets were held in Adelaide, Sydney, and London to celebrate the event.

His next work was to construct the line connecting South Australia with West Australia, and shortly afterwards he received the honour of knighthood in the order of St. Michael and St. George.

In addition to his labours as Postmaster-General and Superintendent of Telegraphs, Sir Charles Todd faithfully and successfully attended to the duties of his office as Government Astronomer.

The Observatory was furnished with a fine equipment of astronomical and meteorological instruments, including an 8-inch Cooke equatorial (brought out in time for the transit of Venus observations in 1874), an excellent 6-inch transit-circle by Troughton & Simms, photographic barograph and thermograph, etc.

In 1882 December he journeyed to Wentworth, and obtained good observations of the transit of Venus at that station.

In 1895 he was consulted by the West Australian Government in regard to the establishment of their new Observatory. Sir Charles selected a commanding and beautiful site on the top of Mount Eliza, on the outskirts of Perth, and advised as to the buildings and the procuring of the best modern instruments. His chief assistant, Mr. W. E. Cooke, was chosen to be the new Government Astronomer at Perth.

Sir Charles took a special interest in meteorology, and trained and organised his large army of postal officials to become meteorological observers, all the important post and telegraph stations in the State being equipped with rain-gauges or other meteorological instruments. The publications of the Adelaide Observatory thus contain a very complete record of the climatic and meteorological conditions of the State.

He also was keenly interested in every effort for the progress of science, and was the author of numerous scientific papers. He was President of the Astronomical Society of the State from its inception till his death, and was prominently connected with many other scientific bodies and public institutions. He was honoured in England by being elected a Fellow of the Royal Society, and in 1886, when revisiting England, received the honorary M.A. degree from the University of Cambridge. Two foreign scientific bodies also conferred distinctions upon him. Although his greatest success was achieved as Postmaster-General, he was at heart really an astronomer, and throughout his long life was filled with the keenest interest and enthusiasm for the science. This explains how it was that, in addition to his arduous labours in the Post Office, he was able to successfully organise and attend to the work of an observatory.

He retired in 1906 December, after spending half a century in the service of the colony, and sixty-five years in the service of the empire. A very real compliment was paid to him by the State Parliament, which refused to pass an act for the compulsory retirement of septuagenarians so long as he remained in the South Australian public service.

He died on 1910 January 29 in his eighty-fourth year, honoured and beloved by all, and left one son, Dr. C. E. Todd, and four daughters, Lady Todd and his eldest son Mr. Hedley Todd having predeceased him.

Sir Charles Todd was the author of numerous papers in the *Monthly Notices* dealing with his observations at Adelaide, especially with the phenomena of Jupiter's satellites and observations of comets.

He was elected a Fellow of the Society 1864 April 8.

[The Council are indebted for the above notice to Mr. G. F. Dodwell, Government Astronomer, South Australia.]

Frederick William Watkin, youngest son of the late Reverend John Woodlands Watkin, D.D., vicar of Stixwold, Lincolnshire, was born there, 1859 March 20. He was educated at Manchester Grammar School and Corpus Christi College, Oxford, where he won the junior mathematical scholarship. In 1883 he was appointed a master at St. Paul's School, and took charge of the recently created Science Side, which, during his twenty-six years of service to the school, grew to rival the Classical Side in numbers and success. For many years he was a house-master, and shortly before his death he was appointed Surmaster of the school.

Mr. Watkin married in 1898 Mary Elizabeth Simpson, eldest daughter of the late Robert Henry Simpson. He died 1910 April 6, leaving a widow and four children.

He was elected a Fellow 1884 February 8.

With the death of Johann Gottfried Galle the curtain finally descends upon the great drama of the discovery of Neptune, the opening scenes of which thrilled the whole world two-thirds of a century ago. The end is calm after storm. The exit of the last actor stirs no memories of conflict save by association, for Galle took no part in the scenes where the battle raged. His own honourable share in the discovery was never seriously questioned; he made no claims likely to be disputed, but, on the other hand, excited admiration by the modesty with which he ceded all glory to Le Verrier. In a long and tranquil life devoted to astronomical work he won ample recognition for himself independently of his share in the great discovery; and now, twenty years after all the other actors have left the stage, Galle, full of years and honours, makes his farewell to a generation which first heard his name and fame from their grandfathers.

Galle was elected one of our Associates on 1848 May 12, several years before the oldest existing Fellow was elected, and for some time past he has therefore been the "Father of the Society." The interval of eighteen months between his observation of Neptune (1846 September 23) and his election as Associate would probably have been even shorter but for the circumstance that the election of Associates was formerly left to individual initiative, which apparently did not "secure a proper attention to the names of rising astronomers" (*Mon. Not.*, viii. p. 79). The Council accordingly took the matter into their own hands in February 1848, and the result was the election of twenty-one associates in a body on May 12. The second name in the list is that of Dr. C. Bremiker, whose map of Hora xxi. was used by Galle in finding Neptune. Three of the twenty-one, Faye, Galle, and O. Struve, survived their election by more than half a century, the death of Faye in 1902 closing the long partnership.

Johann Gottfried Galle was born, 1812 June 9, at Pabsthaus, near Wittenberg, the eldest of seven children. He got early instruction from a neighbouring pastor, and then went to the Wittenberg Gymnasium till 1830, when he entered the Berlin University, graduated after three years, and was in 1833–5 mathematical master in the gymnasiums at Guben and Berlin.

In 1835 he was appointed Encke's single assistant at the new Berlin Observatory, and devoted sixteen years to work with the refractor of 9 Paris-inches aperture. In 1838 he discovered the crêpe ring of Saturn, and Encke mentioned the discovery twice to the Berlin Academy, without, however, laying much stress on it, as he was more interested in "Encke's division" between the rings. Galle did not trouble about wider publication, and when Dawes and Bond noticed the crêpe ring in 1850 they made practically a new discovery. Galle thereupon (in 1851) called attention to his earlier observations (*Ast. Nach.*, No. 756) and elicited a reply from Dawes (*Mon. Not.*, xi. p. 185) in which ungrudging credit is accorded to Galle, combined with a very reasonable expression of regret that more stress had not been laid on the observations. It appears that Galle made six days' micrometric measurements which established the main facts, but which Encke did not consider worth communicating to the Berlin Academy in his paper on Saturn; and Dawes writes:—

"It is to be regretted that Dr. Galle's observations and measures were not published in the *Astronomische Nachrichten* soon after they were made, as they would long since have directed attention to this remarkable phenomenon."

It is all too easy to point out faults of omission after the event, but it is almost impossible to study the surroundings of the discovery of Neptune without turning a strong light on such details. We shall presently see that this was not the only occasion on which Encke was apathetic at an important moment; his attitude might have had the result of discouraging Galle's search for the new planet. There might have been, at any rate, a few weeks' delay, in which, conceivably, Challis might have realised that he had already found the planet. What a difference that would have made in history! Airy and Encke would have changed places, and Encke would indeed have been in much worse plight than Airy was if it could have been said that he had discouraged acting on the letter given below. Encke owed much to Galle and d'Arrest.

In the winter 1839–40 Galle discovered three comets in rapid succession (on 1839 December 2, 1840 January 25, and 1840 March 6), which attracted the more attention that no new comet had been found for five years previously. The King of Denmark honoured the triple discovery with three Comet medals (*Ast. Nach.*, 400). A diary of Galle's tells us that the first of these discoveries was quite accidental. He was experimenting, on the Fraunhofer lines, with a glass prism attached to a theodolite in the observatory, and had got up at 3 a.m. to look at the spectrum of Venus.

Glancing over the heavens he saw a nebulous star near γ Virginis which he did not remember to have seen before, and turning the telescope on it found that it was a comet.

Comets occupied a large share of Galle's working life, for he contributed to Encke's 2nd edition of Olber's *Abhandlungen über die Bahn eines Cometen* a list of the elements of 178 comets; he himself prepared a 3rd edition of the whole work in 1864; and in 1894, at the age of eighty-two, he prepared (with the aid of his son, Dr. Andreas Galle) a comprehensive list of the elements of the orbits of 414 comets.

In 1851 he was appointed Director of the Breslau Observatory in succession to Boguslawski, and this position he held till his retirement in 1897. Perhaps the most noteworthy incident of this long career of devoted astronomical work was the suggestion in 1872 of the present accredited method of determining the solar parallax by the observation of a minor planet. He put his suggestion into successful practice in 1873 by the observation of Flora, obtaining the excellent pioneer result $8''{\cdot}82 \pm 0''{\cdot}06$.

But it is inevitable that he should be chiefly remembered in connection with Neptune, and little excuse is needed for recalling once more all the circumstances relating to that eventful night when he verified Le Verrier's prediction in the sky. A year before he had sent Le Verrier his new reduction of Roemer's observations. A great fire destroyed the bulk of these observations in 1728, and only a fragment, giving the observations for the three days (Triduum observationum astronomicarum) October 20–23, 1706, were rescued. They had been used by Tobias Mayer for proper motions, but for various reasons a new and more careful reduction of this precious fragment seemed desirable, and Galle undertook it as his dissertation for a Doctor's degree. He took immense pains with the work, and was so much impressed with its value that he thought it might help Le Verrier in the researches on the orbits of the planets on which he was known to be engaged. Before considering Le Verrier's reception of the memoir, we may glance for a moment or two at the memoir itself, which is now scarce (there is, for instance, no copy in our R.A.S. Library). It is written in Latin, with such simple directness that there is no difficulty in following it, even for the unskilled. He explains how Roemer had used Tycho's instruments, but preferred to observe R.A.'s directly, using three clocks for the purpose, one in the instrument-room being compared constantly with two others kept in closed cases. He relates also how Roemer had first observed from a tower, but found the wind troublesome, and so came down into his house in 1690. "Ob altitudinem vero turris rotundæ venti et tempestas observationibus sæpius obnoxia erant, et Roemerus a MDCXC in domus suæ fenestra meridionali machinam transitibus per meridianum inservientem construxit." After a careful reduction, Galle gives on pp. 33–34 a catalogue of the positions of 88 stars, and compares them with the observations of Bradley and Piazzi; and then three observations of the Sun, the Moon,

Mercury, Venus, Mars, Jupiter, and Saturn; and he calculates the obliquity of the ecliptic from a few observations of the Sun not belonging to the three days, but preserved by Horrebow.

Le Verrier did not acknowledge the receipt of the memoir for a year. (Correspondence was apparently leisurely in those days, and this fact is worth remembering in connection with other incidents of the drama.) He then wrote the following letter, which was first printed in *Himmel und Erde* by Professor Scheiner of Potsdam, by permission of Professor Galle:—

À Monsieur J. G. Galle,
Astronome à l'Observatoire Royal de Berlin à Berlin.

Paris, le 18 Septembre 1846.

Monsieur,—J'ai lu avec beaucoup d'interêt et d'attention la reduction des observations de Roemer, dont vous avez bien voulu m'envoyer un exemplaire. La parfaite lucidité de vos explications, la complète rigueur des résultats que vous nous donnez, sont au niveau de ce que nous devions attendre d'un aussi habile astronome. Plus tard, Monsieur, je vous demanderai la permission de revenir sur plusieurs points qui m'ont interessé, et en particulier sur les observations de Mercure qui y sont renfermées. Aujourd'hui je voudrais obtenir de l'infatigable observateur qu'il voulait bien consacrer quelques instants à l'examen d'une region du ciel, où il peut rester une Planète à découvrir. C'est la theorie d'Uranus qui m'a conduit à ce résultat. Il va paraître un extrait de mes recherches dans les *Astronomische Nachrichten*. J'aurai donc pu, Monsieur, me dispenser de vous en écrire, si je n'avais eu à remplir le devoir de vous remercier pour l'intéressant ouvrage que vous m'avez adressé.

Vous verrez, Monsieur, que je démontre qu'on ne peut satisfaire aux observations d'Uranus qu'en introduisant l'action d'une nouvelle Planète, jusqu'ici inconnue; et ce qui est remarquable, il n'y a dans l'écliptique qu'une seule position qui puisse être attribuée à cette Planète perturbatrice. Voici les elements de l'orbite que j'assigne à cet astre:

Demi-grand axe de l'orbite	36·154
Durée de la revolution sidérale	217·387 ans
Excentricité	0·10761
Longitude du Perihelie	284°45′
Longitude moyenne 1er Janvier, 1847,	318°47′
Masse	1/9300
Longitude Heliocentrique vraie au 1er Jan. 1847	326°32′
Distance au Soleil	33·06

La position actuelle de cet astre montre que nous sommes actuellement, et que nous serons encore, pendant plusieurs mois, dans des conditions favorables pour le découvrir.

D'ailleurs, la grandeur de sa masse permet de conclure que la grandeur de son diamètre apparent est de plus de 3″ sexagesimales. Ce diamètre est tout-à-fait de nature à être distingué, dans les bonnes lunettes, du diamètre factice que diverses aberrations donnent aux étoiles.

Recevez, Monsieur, l'assurance de la haute consideration de votre dévoué serviteur, U. J. Le Verrier.

Veuillez faire agréer à Mr. Encke, bien que je n'aye pas l'honneur d'être connu de lui, l'hommage de mon profond respect.

When he received this letter on September 23, Galle consulted his chief. Encke was not enthusiastic, was even dubious; and Galle must be given full credit for persisting, in spite of the lukewarm attitude of his superior officer. A young student who had been allowed to take up his quarters in what was intended for an anteroom at the observatory, counted for far more in the way of encouragement; he begged permission to be present; he apparently waited patiently until Galle had made his first scrutiny hoping to detect the planet by its disc, and when nothing came of this he suggested hunting for a star map. Galle took the suggestion, and led his companion to a cupboard which he knew contained all available star maps. The visit was not made with any great alacrity, for Galle had been observing in the region some time before, and had realised the deficiencies of Harding's map.

But the visit was made, and by a fortunate chance a new map was found, Bremiker's Hora xxi., printed but not yet distributed. There had been a delay in the distribution, and here again speculations have been formulated as to the changed course of events if that distribution had not been delayed. Challis might have had the map, and then——? But we must stick to the facts. Galle and d'Arrest found the map and carried it to the telescope: d'Arrest put it on a desk and verified the stars which Galle called out at the telescope. Presently there came an object which was not on the map. Encke (who was celebrating his fifty-fifth birthday in the family circle) was told the news and took part in the further observations. The object was followed as long as possible, but neither from the disc nor from the motion was it certain that a planet had been found. The mean time of observation for the night of September 23, given in *Mon. Not.*, viii. page 155, is midnight, and the planet set about 2·30 a.m. Its motion was 3″ per hour. The observers must wait with patience till the next night. Fortunately the weather was excellent (as is clear from the fact that observations of the planet were secured on September 23, 24, 25, 26, 27, 28, 29, *loc. cit.*), and the motion was soon verified. On September 25 Galle wrote to Le Verrier, "La planète dont vous avez signalé la position existe réellement," and Le Verrier communicated the intelligence to

the Academie des Sciences on October 5. He replied to Galle as follows:—

Paris, 1846 Octobre 1.

Monsieur,—Je vous remercie cordialement de l'empressement que vous avez mis à m'instruire de votre observation du 23 et du 24 Septembre. Grace à vous, nous voilà definitivement en possession du nouveau monde. Le plaisir que j'ai éprouvé de voir que vous l'avez rencontré, à moins d'un dégré de la position que j'avais donnée, est un peu troublé par l'idée qu'en vous écrivant plus tôt, il y a quatre mois, nous aurions obtenu dès lors le resultat que nous venons d'atteindre. Je communiquerai votre lettre, lundi prochain, à l'Academie des Sciences. Permettez-moi d'espérer que nous continuerons fréquemment une correspondance qui commence sous d'aussi heureux auspices.

Je suis sous une haute consideration, votre dévoué serviteur,—

U. J. Le Verrier.

Le Bureau des Longitudes s'est prononcé ici pour *Neptune*. Le signe un *trident*. Le nom de Janus indiquerait que cette planète est la dernière du système Solaire, ce qu'il n'y a aucune raison de croire.

And so the name and sign of the planet were fixed within a week of discovery! Galle had suggested the name Janus, because he had some little time previously learnt in a lecture that Janus was a predecessor of Saturn. Le Verrier's comment in the postscript, objecting to limit the solar system, is full of interest.

Galle, as already remarked, claimed no share in the discovery, which he assigned entirely to Le Verrier. He nevertheless received from Paris the cross of the Legion d'Honneur, and, for the second time, the Prix de Lalande.

The following letter from Airy to Galle has no direct bearing on the events just related, but is of interest as illustrating Galle's relations with another important actor in the drama. Dr. Andreas Galle informs me that, so far as he knows, his father received no letters from Adams or Challis:—

Royal Observatory, Greenwich, 1847 October 14.

Dear Sir,—I should, on my return to Greenwich, have written to you as early as possible, to acknowledge the kindness with which you devoted so much time to me at Berlin. But I found much business waiting for me when I returned, and I was very soon occupied with arrangements for the observation of the solar eclipse. As it was doubtful whether the eclipse would be annular at Greenwich, I selected four stations to the north of Greenwich and three to the south, and equipped all with observers and instruments. Unfortunately the weather was so bad that only at one station was the eclipse seen at all, and then only for a few minutes.

I have lately written to Lt.-Colonel Bayer respecting the Prussian Survey and its connection with those of the neighbouring kingdoms. If you should see him, you may possibly be able to add something to my explanation of the nature of my wants.

I left Berlin by the early train on the morning after I last saw you, and saw Mr. Schumacher in the evening and on the next day. He appeared to be extremely well, but was then much oppressed with letters. There were then some comets on his hands. I have nearly given up the observation of comets here: the usual business and the addition caused by the use of my altitude and azimuth instrument, occupy all the time of my assistants.

* * * * * * *

I hope to see you in England.—I am, dear Sir, yours very truly, G. B. Airy.

Galle married a daughter of Professor Regenbrecht, of Breslau, and had two sons, who survive him, Professor Dr. Andreas Galle, of the Geodetic Institute at Potsdam, and Dr. Georg Galle, a physician in Hirschberg: they are both married, and there are nine grandchildren. Galle's early working years were clouded by much domestic sorrow. His mother died in 1839, and a second wife whom his father married followed in 1848. A brother died in 1844, a sister in 1847, another brother in 1852, his father in 1853. All six of his brothers and sisters were gone by 1866, leaving the eldest to survive them by forty-four years.

In 1830 Galle made a journey on foot from Berlin to the Rhine and Switzerland; he saw the first steamer on the Rhine, and on his return to work used a steel pen for the first time. He knew Bessel and Alexander von Humboldt, and often helped the latter with various small calculations required in the writing of the *Kosmos*. As a student in Berlin he attended the lectures of Hegel (Philosophy); Ohm, Dirksen, Plücker, Dirichlet (Mathematics); Encke, Ideler (Astronomy); Erman, Seebeck, Dove (Physics); Ritter (Geography); Weiss (Mineralogy); Schultz (Botany); Wichmann (Zoology); Mitscherlick (Chemistry).

His ninetieth birthday on June 9, 1902, was honoured by deputations from the Astronomische Gesellschaft, the Astrophysical Institute of Potsdam, the Berlin and Breslau Observatories, and several other bodies. He answered all the letters of congratulation himself on this and other occasions up to his ninety-eighth birthday last year, when his son took over the correspondence. Many honours were conferred upon him independently of those at his jubilee.

He died on July 10, 1910, in his ninety-ninth year.

(To Dr. Andreas Galle the writer is indebted for much kind help and information, both direct and through the help formerly given to Mr. F. A. Bellamy, for his comprehensive biography in *Knowledge* for August and September 1910. The help given by Mr. Bellamy is also gratefully acknowledged.) H. H. T.

Giovanni Virginio Schiaparelli was born at Seviglano in Piedmont on the 14th of March 1835. His parents originally came from Biella, in the Novara province, and were probably of well-to-do circumstances, as they were able to enter their son in his seventh year at the Gymnasium Lycée of Seviglano, where he remained for nine years until July 1850. In the following November he was admitted to the mathematical course at the University of Turin, where he studied under Plana, Billotti, and other mathematicians. Here he gained a high reputation with his professors, and rapidly outdistanced his fellow-students in the study of pure and applied mathematics and in drawing, so that in August 1854 he graduated with honours as a hydraulic engineer and civil architect. On leaving the University he devoted himself to private teaching of mathematics at Turin, which gave him some means of livelihood, and enabled him to take up at the same time the study of modern languages and of astronomy.

In his early life Schiaparelli had shown evidence of a strong versatile and precocious genius. This attracted the notice of Paolo Dovo, a theologian of Seviglano, of whom Schiaparelli wrote that "he was a man of gold, a great lover of astronomy, and one whose image could never be erased from the memory of those who had known him." There can be no doubt that it was the influence and teaching of Dovo that laid the first seeds of that unceasing devotion to astronomy which he displayed throughout his life.

In November 1856 he held for a short time the post of teacher in elementary mathematics in the Gymnasium of Porta Nuova at Turin, but his love of astronomy, and the field for research that it offered, made him reluctant to continue in a position that was distasteful; he accordingly made great efforts to obtain assistance to enable him to pursue his astronomical studies abroad, which, happily, by the influence of his friends, was accomplished by the Sardinian Government making a grant of money for that purpose.

In February 1857 Schiaparelli went to Berlin, where for two and a half years he pursued his studies under Encke. His versatile mind was not satisfied by astronomy alone, and during this period he studied philosophy under Michelet, geography under Ritter and Kiepert, meteorology under Dove, physics under Poggendorf, and terrestrial magnetism under Erman. In considering the life of one who contributed so much to astronomical science, it is interesting to note the comprehensiveness of his studies and his tastes, which were developed not only in the mysteries of nature, but also in intricate historical questions, and in the realms of literature and art.

Anxious to learn practical astronomy, Schiaparelli, in June 1859, obtained admission to the observatory of Pulkovo, where, under Struve and Winnecke, he remained for twelve months in what was perhaps the best school of instruction in observation and calculation. In July 1860 he received the appointment of second Astronomer to the Brera Observatory at Milan under Carlini. At first he was not received with much encouragement, but his

vigorous intellect asserted itself, so that on the death of Carlini in 1862 he was, with unanimous approbation, appointed Director. From this period till his death Milan was the scene of all his astronomical activity—for forty years at the observatory, and for ten years after his retirement at his residence in Milan.

As a professor, Schiaparelli, within the period 1863 to 1875, gave several courses of lectures at the Royal Technical Institute at Milan on Theoretical Geodesy, and Spherical Astronomy; and at Pavia, in 1875–76, on Descriptive Astronomy, and Celestial Mechanics; but lecturing had no attraction for him, and from this time he gave it up.

Schiaparelli's scientific labours are to be found in 256 separate publications, but his contributions to science should not be measured solely by his published work, for his correspondence with scientific men was most voluminous, and it is to be hoped that some of it may one day be given to the world.

Within the limits of this notice it is only possible to refer briefly to his work. His first discovery was that in 1861 of the minor planet Hesperia (68). In 1864 he sent to the *Astronomische Nachrichten* "an elegant and probably original contribution to the theory of the orbits of bodies moving freely in space, and acted on only by their mutual attractions." In this paper he established that when three bodies move in space under the influence of their mutual attractions, the three osculating planes of the trajectories and the plane of the three bodies meet in a point, which point is the centre of gravity of the three bodies, each mass being augmented proportionally to the cube of the distance of the other two bodies. The exhaustive discussion of his very careful observations and drawings of Comet III. 1862 forms a valuable memoir in No. 2 of the Publications of the Brera Observatory. His explanation of the phenomena presented by the tail of this comet, and the conclusions he draws as to the influence of the Sun, and as to the mutual repulsion which the particles of the tail exercise on each other, have an interesting bearing in explaining phenomena of recent comets.

Schiaparelli's remarkable discovery in 1866 of the connection between the orbits of comets and meteors, for which in 1872 he was awarded the Gold Medal of this Society, is so well known that any detailed account here is hardly necessary. His discovery established the relation between the August meteors and Comet III. 1862, and also that between the November meteors and Comet I. 1866. His account is contained in a series of five letters to Secchi, dated from September 1866 to February 1867, and published in the *Bulletino Meteorologico del Collegio Romano*. In a communication to the *Astronomische Nachrichten* he sums up his results with this remarkable question, "Must we regard these falling stars as swarms of small comets, or rather as the product of the dissolution of so many great comets? I dare make no reply to such a question." In this connection his eminent fairness is shown in a letter to Delaunay, of March 12, 1867, wherein he says: "It would be

unjust not to mention that the relation between comets and falling stars was surmised by Chladni in his work *Der Feuermeteoren* in 1819, and that the necessity for great eccentricity in the orbits of meteors had already been recognised by Professor Newton in the Brussels *Annuaire* for 1866."

At the opposition of the planet Mars in 1877, Schiaparelli commenced the long and highly important series of observations which he continued until the opposition of 1897, and which together form the most complete monograph of the physical appearance of the planet which we possess. These are contained in seven memoirs published by the Reale Accademia dei Lincei, besides some subsidiary memoirs. The first important result of these observations was the accurate determination of the planet's axis of rotation, obtained from the exhaustive discussion of a very large number of micrometric measurements of points on its surface. The topography and physical features which he delineated showed that the surface is crossed by a great number of fine lines to which he gave the name of "canali." At the oppositions of 1877 and 1879 these canali were shown as single lines, but in 1882 and at subsequent oppositions he described them as duplicated and running in parallel lines. Comparing his observations with those of Lowell, he was inclined to think that the gemination of the lines was periodic, and made its appearance when the heliocentric longitude of Mars was about 110° or 120°, some two months after the spring of the northern hemisphere. Such unexpected phenomena excited a large amount of criticism and scepticism, which indeed up to the present day is not yet allayed. Schiaparelli had proved himself in so many ways to be a most careful, accurate, and conscientious observer, that though some observers of high excellence have altogether failed to confirm his observations of these "canali," it is impossible to believe that they have not some objective existence.

The explanation of these discrepancies is probably due to the varying character of the phenomena, and to some misconception from the delineation having been rendered so strongly in the engravings as to create an erroneous impression of phenomena exceedingly difficult to perceive. Schiaparelli had early shown that these delicate features are somewhat fleeting, and in a letter to the writer of this notice in 1882 he says: "Il est indubitable que les taches de Mars sont sujettes à des variations considérables de couleur et d'intensité ; les lignes obscures ne sont pas toujours visibles, et ne sont pas toujours bien nettes. De là en partie les différences entre les observateurs dont on pourra peutêtre donner l'explication plus tard, lorsque notre connaissance des phénomènes sera plus complète. Par les nouvelles observations l'exploration des taches devient plus difficile qu'on ne le croyait. Il ne reste que s'attacher avec le plus grand soin à la constatation des faits." In a later letter, in 1897, he writes: "J'ai pu constater l'existence du *Pons Achillis*, comme un filet brillant entre deux taches bien sombres. Ce *Pons Achillis* n'est pas toujours également visible :

en 1888 il a disparu presque complètement entre le 25 et le 30 Mai. Le 30 Juin suivant il était de nouveau à sa place avec son aspect ordinaire."

No more noteworthy discoveries in astronomy were made by Schiaparelli than those contained in his researches on the axis and period of rotation of Mercury and of Venus.

The *Rendiconti del Accademia dei Lincei*, published in 1889, contains his memoir on Mercury, which he had observed from 1881 to 1889, making in that period 150 drawings of the markings on the planet, mostly in the daytime. His conclusion was that the aspect of the spots was always the same in similar positions of Mercury with regard to the Sun and the Earth, so that the rotation would take place in the same time in which the planet makes one sidereal revolution round the Sun. He found that the axis of rotation is nearly perpendicular to the orbit, and in consequence of the considerable eccentricity of the orbit there would be a libration of 47° in longitude, so that about $\frac{2}{3}$ of the surface of the planet would never receive the Sun's light.

Schiaparelli had previously made a series of observations of the markings on Venus, which were published in 1890 in five memoirs in the *Rendiconti del Reale Istituto Lombardo*, vol. xxiii., and which contain a very complete discussion of all the earlier physical observations of the planet. He concluded that the rotation of Venus is very slow, and is such that no appreciable variation in the spots is discernible in a month. From his observations the period of rotation would appear to lie between six and nine months, and the most probable explanation was that the rotation is a period of 224·7 days, the same as the sidereal revolution of the planet round the Sun. He also concluded that the axis is perpendicular to the orbit, with a possible variation of 10° to 15°. These results, for Mercury as well as Venus, were entirely discordant with all previous observations, and they introduced a new and wholly unexpected problem into our view of the solar system. It is satisfactory to record that his conclusions with regard to Venus are shown to be in perfect accordance with observations by Gruithuisen in 1813 and 1814, and by Denning in 1881, and they have since been confirmed by Perrotin, Holden, Lowell, and other observers. In a more recent memoir in 1895 Schiaparelli wrote: "From the investigation I have made up to the present time, I conclude that the period of 224·7 days announced by me in 1890 as probable, seems now to be placed entirely beyond doubt."

From the year 1875 to 1900 Schiaparelli was a devoted observer of double stars, his observations being of the most refined character. His results are contained in three catalogues. The "first series" published by his Observatory in 1888 consisted of 465 binaries selected from the catalogues of Dorpat, Pulkovo, and Burnham, which were measured with the 8½-inch Merz refractor of the Brera Observatory. A catalogue of the measurements of 32 binaries, having rapid orbital motion, made also with the 8½-inch

refractor, was published by the Istituto Lombardo in 1882. From 1886 to 1900 Schiaparelli made all his observations with the 18-inch Merz-Repsold refractor. These are to be found in two catalogues, one of 99 stars made 1886 to 1888, and the other forming the "second series," of measures of 636 binaries made from 1886 to the end of his Directorate of the observatory in 1900. This long series of high-class observations bear witness to the great power for work with which Schiaparelli was endued—the vigour of a genius which would tolerate no limits, either to activity or to study. And the amount of work he accomplished is more remarkable, seeing that in the summer months he was quite incapacitated by the heat. In one of his letters he writes: "The heat is great, and the processes of life and work proceed at the lowest possible pressure, I am incapable of doing anything." And the depression thus caused by the hot weather is shown in the sad utterance that follows: "to sleep and not to wake again would be what would please me best now." The summer days being passed, he resumed his normal activity.

It is impossible to refer here to many of his numerous contributions and efforts for the advancement of knowledge. The publications of the Brera Observatory bear witness to his researches in the astronomy of the Greeks, and particularly his history and investigation of the theories of the solar system by the forerunners of Copernicus among the ancients, written on the occasion of the celebration of the four hundredth anniversary of the birth of Copernicus. Schiaparelli was an exceptionally good Latin scholar and able to write excellent Latin verses. He was also acquainted with Arabic; and when Professor Nallino went to the Escurial to examine and copy the unique Arabic MSS. of Al Battani contained in that celebrated library, Schiaparelli associated himself in the publication of that important work, the Arabic text and Latin translation of which appeared in three parts, forming No. xl. of the Publications of the Brera Observatory. This work had never before been fully translated, for the Latin translation of Platon Tiburtin gave only a portion of the text and omitted all the tables. Schiaparelli took charge of all the purely astronomical matter, as well as the verification and correction of the numerous copyist's errors in the tables, and he supplied in Latin many comprehensive notes and emendations. The work now forms one of the most precious contributions to Oriental Astronomy which we possess.

After his retirement from the observatory, Schiaparelli devoted much study to Babylonian Astronomy, and among his latest publications are found treatises on the origin and progress of astronomy with the Babylonians, and papers on observations of Venus and Mars at Babylon. Schiaparelli was a profound theological scholar. He knew all the sacred books of the principal religions, and had made a deep study of the foundation and historical development of Christianity, and he was quite *au courant* with modern biblical criticism; indeed, so profound was his knowledge of these subjects

that his successor, Professor Celoria, has asserted that "there have been and are few men in Italy so competent as Schiaparelli to occupy a chair of comparative religion." In 1903 he published a book on the Astronomy of the Old Testament, and also a paper on the astronomical allusions in the book of Job.

Numerous papers and researches in astronomy might have been advantageously referred to, but probably enough has been said to show what Schiaparelli was. An insatiable thirst for knowledge, a vigour of intellect that knew no inactivity, a versatility without apparent limit—these were the characteristics that actuated him throughout his life, and which enabled him to accomplish so much for the advancement of astronomy that he must ever hold an illustrious place in the annals of the science.

Schiaparelli was married in 1865 to Maria Comotti, by whom he had two sons and three daughters. Her death took place in 1893.

The conclusion of his life is of the saddest, for in his last years his eyesight failed and he became totally blind. He died at Milan, after a short illness, on 1910 July 4.

He was elected an Associate of this Society 1872 November 8.

E. B. K.

Proceedings of Observatories.

Royal Observatory, Greenwich.
(*Director, Mr. F. W. Dyson, Astronomer Royal.*)

Transit-circle.—During the year, 10,019 observations of transits and 10,088 observations of meridian zenith-distances have been obtained. The Sun has been observed 153 times and the Moon 98 times. Reflexion observations of stars have been obtained on 80 nights.

The stars observed during the year are taken from a working catalogue containing the fundamental stars observable in this latitude, and all stars down to $9^{m}\cdot0$ and a few fainter ones within the limits 24° to 32° of N. declination. The latter will serve as reference stars for the plates in the Oxford zone of the Astrographic Catalogue. Their observation was begun in 1906 and should be finished in 1915.

Altazimuth.—During the year, 1743 observations of meridian transits have been obtained. The Moon has been observed 75 times on the meridian, and 30 extra-meridian observations during her first and last quarters have been made. The number of reflexion observations of stars is 137.

Some progress has been made with the Altazimuth Ten-year Catalogue for the years 1899–1908, mentioned in the last Report.

From the beginning of 1905 the lunar crater Mösting A has been observed when possible at Greenwich and at the Cape Observatory. Up to 1910 November 21 there were 113 common dates on which observations were secured at both observatories. Arrangements have been made, in conjunction with H.M. Astronomer, for these observations to be discussed, with a view to a determination of the Moon's parallax by this direct method.

Reflex zenith tube.—During the year, 1362 double observations of stars have been obtained.

Considerable progress has been made with the discussion of the observations secured with this instrument since 1903, and more especially since 1907, when an extended programme of observation was adopted.

Occultations.—During the year, 63 disappearances and 8 reappearances of stars occulted by the Moon have been observed by one or more observers. Of these, 13 disappearances and 8 reappearances were observed during the lunar eclipse of November 16.

28-inch Refractor.—700 double stars have been measured, each star generally on 2 nights. These consist of—

117	pairs	under	$0''\cdot5$ separation.
143	,,	between	$0''\cdot5$ and $1''\cdot0$ separation.
172	,,	,,	$1''\cdot0$,, $2''\cdot0$,,
268	,,	over	$2''\cdot0$ separation.

κ Pegasi and δ Equulei were each measured on 5 nights, and 70 Ophiuchi on 9 nights.

Measures of the diameter of the ball and rings of Saturn were made on 7 nights.

Thompson Equatorial.—This instrument has been largely employed in the determination of the position of faint satellites and of comets. With the 26-inch refractor 70 photographs of Neptune and its satellite have been obtained on 23 nights. With the 30-inch reflector Jupiter's Eighth Satellite has been photographed 9 times on 5 nights, and Saturn's Ninth Satellite 11 times on 7 nights. Long series of observations have been made of Halley's Comet (32 photographs on 23 nights), of Daniel's Comet (26 photographs on 13 nights), and shorter series of Metcalf's (1910*b*), Faye's (1910*e*), and Comet 1910*a*: 18 photographs of 3 minor planets have also been taken.

In addition, Mars has been photographed 34 times on 16 nights in order to determine its position when at a greater distance from opposition than is given by the meridian observations.

Attention has also been given to improving the adjustments of the 26-inch refractor preparatory to its use in the determination of parallaxes of stars. It is proposed to work in the first place on the Kapteyn areas which fall in the Greenwich astrographic zone (Dec. 64° to North Pole).

A few photographs of long exposure have been taken with the reflector and a number of miscellaneous plates for various reasons.

The following results have been published in the *Monthly Notices*:—Observations of Minor Planets, 1908 and 1909; Comets 1909*a* and 1909*b*; Phœbe, 1909; Jupiter's Eighth Satellite, 1910.

The photographs of Comet Morehouse, for determination of the motions of the matter forming the tail, have been measured, but the discussion of the measures is not yet completed.

The calculation of the ephemeris of J VIII has been continued by Mr. Crommelin up to the year 1916. The increasing south declination of Jupiter renders it unlikely that the satellite will be observed at Greenwich during the next few years; it is hoped that the observations may be taken up by astronomers farther south.

Astrographic Equatorial.—With the astrographic equatorial 372 photographs have been taken on 119 nights. In the first three months of the year the instrument was used for photographing Halley's Comet, and Comets 1910*a* and 1910*b*, and for taking photographs of fields of stars to be used in the reduction of plates taken with the Thompson equatorial. From April to October inclusive, photographs, both Chart and Catalogue, were taken of fields of the astrographic zone $+25°$ to $+31°$, the catalogue of which has been published by the Oxford University Observatory. In November and December the instrument has been used almost wholly for taking plates which will form data for an investigation of the photographic magnitudes of stars of the Astrographic Catalogue, Greenwich Section. The fields of the even degrees

of declination are photographed with ten minutes' exposure when at the same altitude as the Pole, and on the same plate the field around the Pole containing Professor Pickering's standard stars is also photographed. By this means the photographic magnitudes of certain stars on each plate of the Astrographic Catalogue will be determined on Professor Pickering's scale, to serve as standards for that plate. The following are the details of the plates taken during the year:—

147 Chart plates and 111 Catalogue plates were taken of the zone $+25^\circ$ to $+31^\circ$ of which 61 were rejected, 25 because the exposure was stopped by cloud, or because they did not come up to the standard of showing faint stars, 25 from faults of setting, and 11 for miscellaneous defects. 36 photographs were taken of comets, 38 of the reference fields around planets, 2 of Nova Lacertæ, and 4 of the field around the Moon at the time of the eclipse of November 16. 23 plates were taken for the photometric investigation, and 11 for adjustment of the instrument. 16 photographs of comets and for trial were taken with the Ross 4-inch lens, which is now mounted on this instrument, and with a similar lens which was lent for experiment.

The computing work of the department has consisted mainly of the preparation of the Catalogue of Right Ascensions and North Polar Distances of the Catalogue of Stars, which will form part of vol. iii. of the Astrographic Catalogue. In continuation of the details of this work given in the Report of last year, the right ascensions and declinations of the remaining 731 stars of the Kasan Catalogue, of the 3461 stars of the Berlin Catalogue, which covers the zone of declination $+70^\circ$ to $+75^\circ$, and of which about 3000 are given in the Dorpat Catalogue, and of the stars in the Christiania Catalogue, included in the zones of declination 69°, 68°, and 67°, have been computed from the measures given in the volumes of the Astrographic Catalogue. The total work of the year amounts to the determination of the positions of about 6000 stars, involving the conversion of the measures of about 14,000 images.

Copy for press has been prepared for the part from the Pole to 75° N. declination.

At the request of Mr. Franklin-Adams, who has kindly promised to pay the salaries of computers specially employed on the enumeration, the number of stars on the series of photographs of the whole sky taken by him are being counted at the Observatory. It is intended to determine the number of stars of different magnitudes in accordance with the scale of Professor Pickering's polar sequence recently published.

Photoheliograph.—Photographs of the Sun have been taken on 180 days during the year 1910. Of these photographs, 403 have been selected for preservation, including 21 with double images of the Sun for determination of the zero of position of the wires.

The photographs taken at Greenwich have been chiefly supplemented during the year 1910 by photographs taken at the Royal Observatory, Cape of Good Hope. This series commenced on

March 1, 1910, and 461 photographs, taken on 231 days, and including 17 plates for the zero of position of wires, have been received for the nine months ending November 30. The combined series, Greenwich and Cape, represents 259 days out of the 275 days, March 1 to November 30. Photographs have also been received from Dehra Dûn, India, through the Solar Physics Committee, and from the Observatory of Kodaikánal, Southern India, and the daily record made up from the four stations is already complete for the year 1910 up to November 21.

The measurement of the photographs for the year 1910 is well advanced.

The complete photoheliographic results for the years 1907 and 1908 have been printed, and those for 1909 have been passed for press. The number and area of Sun-spots in 1910 is much smaller than in 1908 and 1909.

Longitude Determination.—The observations for the determination of the longitude of Malta have been completely reduced, and copy for press has been prepared. The determination of the geodetic distance between the observing station and the fundamental point at Malta has been undertaken by the War Office. The final result cannot be given until this connection has been made, but the provisional result is—

Longitude of Spencer's Monument (Old Site)
$0^h\ 58^m\ 2^s{\cdot}595 \pm 0^s{\cdot}010$ East.

The result is in complete accordance with the determination by Auwers and Gill, 1875.

Printing.—At the end of the year the Greenwich Observations for 1908 were being distributed. The delayed Photoheliographic Results for 1907 are included in this volume as well as those for 1908.

The Observations for 1909 are printed, with the exception of the Introduction.

Sir W. H. M. Christie, K.C.B., whose tenure of office has been marked by the extension of the activities of the Observatory in many directions, retired on October 1 from the post of Astronomer Royal, which he has held with distinction for more than twenty-nine years.

The Observatory lost the valuable services of Mr. P. H. Cowell on his appointment as Superintendent of the Nautical Almanac on May 2. Mr. S. Chapman, M.Sc., of Manchester University, and Scholar of Trinity College, Cambridge, was appointed a Chief Assistant on December 13.

Royal Observatory, Cape of Good Hope.
(Director, Mr. S. S. Hough, H.M. Astronomer.)

Transit-Circles.—The reversible transit-circle has been employed on the completion of the working programme commenced in 1905, with a view to the formation of a fundamental catalogue. The

observations made throughout by the Repsold-Struve method, with hand guiding, were completed by November 28, with the exception of those of stars within 10° of the South Pole, the observations of which had been temporarily abandoned on account of the pronounced personalities of the different observers when applying this method to very slow-moving stars.

After this date the micrometer was dismounted in order to adapt the clock-driving apparatus supplied by Sir Howard Grubb. This clock motion is actuated by a powerful motor, whose speed can be regulated with all necessary precision by means of a rheostat, and which can be adjusted for different declinations by means of the "cone apparatus" previously supplied by the Société Genevoise. A differential motion, by which the observer maintains the accurate bisection of the star under observation, is actuated by a tangent screw attached to the micrometer box, which operates independently of the clock drive.

The whole apparatus is ready for use, and regular observations have been recommenced. These will be primarily devoted to the observation of the close circumpolar stars omitted from the preceding working list.

The old transit-circle has been in occasional use for time determination and observations of the lunar crater Mösting A.

The number of observations secured with these instruments during the year was as follows:—

Observations of Right Ascensions:—

	Reversible T.C.	8-in. T.C.
Number of Meridian Transits .	4387	274
Determinations of Collimation by collimators	115	51
„ by reflexion and reversal	26	
Determinations of Level . .	623	65
„ Azimuth . .	145	23
Observations of N. Azimuth mark	1175	
„ S. „	1175	

Observations of Zenith Distances:—

Determinations of Z.D. . .	3949	95
„ Runs . .	334	26
„ Nadir . .	720	26
„ Flexure . .	54	11

The observations with the reversible transit include observations of the Sun on 135 days, of Venus on 100 days, and of Mercury on 52 days.

The lunar crater Mösting A has been observed on 33 nights with the reversible transit-circle, and on 20 nights with the old transit-circle.

Heliometer.—The observations of major planets at the time of opposition has been continued and the following secured:—

Opposition of	Neptune	. .	45	obs. on	8 nights.
„	Jupiter .	. .	56	„	7 „
„	Uranus .	. .	40	„	6 „
„	Saturn .	. .	48	„	6 „

The instrument was also used for following the motion of Halley's Comet, and 166 observations for the position of the comet spread over 35 nights were secured.

In addition, 54 observations for the determination of the position of miscellaneous stars, whose places were not available from existing catalogues, were made.

Victoria Telescope.—This instrument has been employed throughout the year, except between the dates March 30 and July 20, in conjunction with the 4-prism spectrograph train, for the photography of stellar spectra in continuation of the previous programme.

Between the above dates the 4-prism head was dismounted and the single-prism head used for photographing the spectra of Halley's Comet and stars.

The instrument was used on 129 nights, the following photographs having been secured:—

With 4-prism spectrograph:—

Photographs of star spectra . . .	239
Daylight plates	40
Focus plates	20

With 1-prism spectrograph:—

Halley's Comet	11
Star spectra	9
Focus plates	11
Extra-focal test plates	16

Astrophysical Laboratory.—During the year 340 plates of stellar spectra have been measured in the Hartmann comparator and 150 star plates, together with 20 solar comparison plates in the wave-length micrometer. The stars measured in the latter comprise 91 plates of 3 of the solar parallax stars not included in the list of observations published in vol. x. of the *Annals*, on account of their small parallax factors, and 59 plates of α Argus and α Can. Maj. taken prior to optical readjustment of the spectroscope.

A discussion of the measures of plates taken previous to July 1907 has been completed, and sent to press to form part 1 of vol. x. of the *Cape Annals*.

6-inch Equatorial.—For the photography of Halley's Comet two half-plate cameras were temporarily attached to the tube of

this instrument. One, used for direct photographs, was fitted with a Dallmeyer lens of 10-in. focus working at F/6, and the second was used in conjunction with the large prism from the 4-prism train of the slit spectrograph. The lens employed with the latter was a Ross-Goertz of $10\frac{1}{2}$-in. focus working at F/7.7. Nineteen direct photographs were taken between April 14th and June 14th. The best of these show a tail 18° long, reaching to the limits of the plate. With the prismatic camera 20 photographs were secured, some of which show the tail spectrum as well as that of the head. The spectra closely agree with those of Comets Daniel and Morehouse.

Astrographic Telescope.—The following photographs have been secured with this instrument during the year:—

Description of Plate.	No. of Plates.	No. of Exposures.	Duration of Exposure.
Kapteyn areas, parallax plates (2nd max.)	13	26	20^m, 20^m
,, ,, ,, (3rd max.)	83	83	20^m
Catalogue plates	4	12	6^m, 3^m, 20^s
Halley's Comet	15	23	various
Eros	9	34	5^m
1852 Comet IV. region . . .	3	6	60^m, 40^m
D'Arrest's Comet region . . .	1	1	60^m
Adjustments	9	...	various

Astrographic Measures and Reductions. — The outstanding measures of the new series of catalogue plates have been completed during the year, and 363 plates of the old series have been measured with a view to the determination of the proper motions of the standard stars.

As a final control of the work, a comparison is now being made between the results derived from the common regions of pairs of plates which overlap. To facilitate such a comparison a preliminary application of the plate-constant corrections is necessary, and it has now been decided to defer publication in order that the printed results may include the corrections as thus applied. During the year these corrections have been computed for 424 plates and applied to the measures for 355 plates. Subject to final revision from comparisons of overlapping areas, the measures from 512 plates have now been completely prepared for press, and the discordances have been examined for 268 quadrants common to a pair of plates. For the extreme northern zone of the Cape series a similar comparison has been rendered possible by the courtesy of Professor Dyson, who has furnished a MS. copy of the measures made at Edinburgh from the plates taken at Perth, Western Australia.

Photoheliograph.—This instrument was received back from Greenwich shortly before the close of the preceding year. A suitable mounting for attaching it to the tube of the astrographic equatorial was constructed locally, and after a few initial experiments it was brought into regular use from March 1. Since that date 550 photographs of the Sun have been obtained on 260 days,

inclusive of 20 plates for the determination of orientation. These plates have been forwarded to Greenwich for measurement and discussion.

Occultations.—Twenty-three separate phenomena of occultations of stars by the Moon have been observed during the year, viz.—

Disappearances at dark limb	19
Reappearances ,, ,,	4

Of these, two disappearances and two reappearances were observed during the total lunar eclipse of November 16. Four of the disappearances were observed by two different observers, and one reappearance by three observers.

Miscellaneous.—Investigations relating to the systematic distribution of the positions and motions of the stars have been continued during the year. A further communication relating to the evidence furnished by the Bradley stars, as confirming the phenomena found from a discussion of the radial velocities, has been made to the Society.

The time-signal service, meteorological observations, and seismograph records have been maintained as in previous years.

Royal Observatory, Edinburgh.
(*Director, Professor R. A. Sampson, Astronomer Royal for Scotland.*)

Transit-Circle.—Observations with the transit circle were confined to those required for time service. The reductions for the Zodiacal Catalogue were completed, the catalogue printed, and distributed in September as *Edinburgh Annals*, vol. iii.

Spectroscope.—Photographs were taken on 10 days, in continuation of last year's series, for the spectroscopic determination of the Sun's rotation. These, as well as the remainder of last year's plates, have been measured; a discussion is in preparation, and will be completed shortly. In March the instrument was adjusted on the Hγ line, and photographs were obtained on 8 days; these have also been measured.

Astrographic Measures.—The measurement of plates taken at Perth, Western Australia, has been continued. All plates in the zone Dec. -40° have been measured, and those for zone -39° from R.A. $0^h\ 5^m$ to $7^h\ 35^m$, with the exception of five plates which have to be retaken.

Copy for press has been made of the whole of zone -40°. The copy, together with the plate constants up to $18^h\ 50^m$, has been sent to the Cape Observatory for comparison with their plates which overlap.

Fifteen-inch Equatorial.—Double-star observations have been continued upon the same programme as hitherto. The weather

was unfavourable. Measures were made of 249 stars, of which 117 were observed on two nights or more. Among these, 33 were of distances less than 1″.

Seismograph.—Observations have been regularly made with the Milne Seismograph; the records have been read and the results communicated to Professor Milne. Some difficulty has been felt, in reading these records, in deciding the limit to which it is useful to follow the very small disturbances. Many of these are of uncertain origin and are troublesome to read.

Meteorological.—Meteorological observations have been carried on regularly. An electrograph for continuous record of air-potential was set up in the summer, and records have been obtained, but the instrument is not yet in continuous working order. Dr. G. A. Carse and Mr. D. MacOwen are co-operating in the work.

Staff.—The foregoing report relates exclusively to work completed or begun under Professor Dyson. On October 1 Professor Dyson was promoted to the charge of the Royal Observatory, Greenwich, and, December 21, Professor R. A. Sampson was appointed to succeed him. Mr. Storey and Mr. Wrigley remain first and second assistants, and on December 28 Mr. Harold Jameson, B.Sc., took up his duties as third assistant. Four ladies are engaged in measuring photographs.

Armagh Observatory.
(*Director, Dr. J. L. E. Dreyer.*)

The preparation for the press of Tycho Brahe's observations of planets and fixed stars is progressing. The collation of the original manuscripts has been completed to the end of 1597, so that only the years 1598–1601 remain to be done.

In connection with the forthcoming edition of the collected papers of Sir William Herschel, an examination has been made of his original observations of nebulæ and clusters, lent by the Royal Society. All objects have been looked up which do not appear to have been re-observed since Herschel's time; also all cases of considerable disagreement between him and later observers. In all, the observations of about 300 objects have been examined in this way. The observing journal has been searched to clear up some difficulties which presented themselves during the revision of the catalogues of double stars.

Cambridge Observatory. (*Director, Sir R. S. Ball.*)

1. *Meridian Circle.*—In the observation of Gill's Zodiacal Catalogue, 251 stars have been observed on 13 nights. The reductions to apparent place are complete in R.A. to 1907 September 23, and in Declination to 1909 October 25; the

reductions to mean place are complete to 1907 September 23. Clock stars were observed daily as far as weather permitted.

The large volume of ledger of observations for the Cambridge Zone Catalogue, now in the press, is printed as far as R.A. $17^h\ 10^m$.

Mr. Hartley has had charge of the observations and reductions in this department.

2. *Sheepshanks Equatorial.* — In continuation of the stellar parallax work, a few plates to complete series have been taken. The persistent bad weather of the past two years has rendered stellar parallax work at Cambridge almost impossible, and the series under observation have been very seriously interrupted.

Mr. H. N. Russell (Princeton, U.S.A.) has published in the *Astronomical Journal*, Nos. 618–19, a summary of the results for stellar parallax deduced from plates taken by him and by Mr. Hinks while he was working at the observatory during the years 1904–1907, and measured by him partly at Cambridge and partly after his return to Princeton. Fifty-two parallaxes are derived, with an average probable error $\pm 0''.036$. The manuscript of the detailed discussion is complete, and the whole will be published shortly by the Carnegie Institution, of which Mr. Russell was a Research Assistant.

The investigations in photographic photometry, referred to in last year's report, have been continued, working on certain of Kapteyn's selected areas. A preliminary account of the results will be presented to the Society at an early date. In the course of this work a new variable or nova was discovered, and announced in *A.N.*, 4448. It has received the provisional designation 97.1910.

A good series of positions of Comet 1910*a*, and of drawings of the structure of the head and shape of the tail, were made in 1910 January. The photographs obtained were of little interest, the great focal length of the instrument and the yellow colour of the comet making photography difficult.

Much time was spent in preparing star cameras for the photographing of Halley's Comet; but owing to the prolonged twilight and bad weather, the results obtained were of the most meagre description.

Mr. Hinks has had charge of the instrument and reductions.

3. *Reduction of Eros photographs and measures for the determination of the Solar Parallax.*—The discussion of the micrometric observations of the planet has been completed, and the result published in Solar Parallax Papers, No. 9 (*M.N.*, 1910 June). The photographic and visual results are in complete agreement.

The manuscript of the photographic catalogue of 6000 comparison stars, with an extensive introduction and comparison, is in the hands of M. Baillaud for publication.

All the tabular matter of the final memoir is completed for press, and the preparation of the account of the whole is making good progress.

4. The usual courses of instruction in practical astronomy, and in field astronomy for surveyors and geographers, have been given by Mr. Hinks during the year.

The Newall Telescope, Cambridge Observatory.
(Professor H. F. Newall.)

The past year has been very unfavourable for observations.

The Newall Telescope has been used in spectroscopic observations. The daylight Comet (1910*a*) which appeared in January was observed on several occasions. Efforts to photograph its spectrum proved unsuccessful, but results of interest were got by visual observation, and were communicated to the Society (*M.N.*, lxx. 459). A great deal of time was devoted to attempts to study Halley's Comet, both with spectroscopic apparatus and with a polariscopic camera, but no results of value were obtained.

Mr. Stratton has completed the discussion, which he undertook in collaboration with Mr. Hinks, of Bryan Cookson's observations on variation of latitude and the constant of aberration; and the results are in the press for publication in the *Memoirs* of the Society. Mr. Stratton is also working at the determination of velocity in the line of sight of certain red stars.

Solar observations with the Littrow spectroscope have been again most seriously hampered by unfavourable weather. Mr. Hubrecht continues his work in this research.

Mr. J. W. Capstick, Fellow of Trinity College, is working in the laboratory on photometric researches in widely separated regions in the spectrum of the electric arc.

Mr. D. Brunt, B.A., Scholar of Trinity College, is engaged in work with the Huggins instruments. It had been decided to make no drastic alterations until practical experience showed the need of them. The work which Mr. Brunt has carried out shows that the clockwork and driving gear are in good condition, and will serve well for the preliminary trials of the spectroscope, which he is putting into adjustment for the study of spectroscopic binaries.

Lectures on Stellar Physics have been given by Mr. Stratton during the October term.

Dunsink Observatory.
(Director, Professor E. T. Whittaker, Royal Astronomer of Ireland.)

The staff consists, as at the close of the previous year, of the Director and Mr. C. Martin, Assistant; the instruments in regular use are the Pistor and Martins meridian circle and the Roberts photographic reflector.

The time-service to Dublin has been continued as in previous years.

Two hundred and eighty-seven plates have been taken during

the year with the Roberts reflector in connection with the observing list of variable stars. Some plates of comets have also been taken.

The new 6-inch doublet was temporarily attached to the Roberts reflector in the autumn, and trial plates were taken. It was then dismounted, and after further modifications is now nearly ready to be replaced.

The professorial courses of post-graduate lectures by the Director and the demonstrations in practical astronomy by the Assistant Astronomer have been given as in previous years, and the South Equatorial has been employed on the first Saturday in each month in showing objects of interest to visitors.

Durham Observatory. (*Professor R. A. Sampson.*)

The Observatory has been fully occupied during the past year in connection with the Tables of Jupiter's Satellites, first in correcting the sheets for press, and next in connection with the publication of the volume. The last previous issue from this Observatory was a volume of observations of circumpolar stars by Carrington, fifty years ago.

Soon after the publication it was discovered that an erroneous formula had been used for certain of the tables for Shadows and Transits. To correct this in a convenient way, a corrected reprint has been made of the tables affected. This has been passed for press, and will be issued very shortly to all who have received the tables.

The tables provide for the complete calculation of phenomena other than eclipses, and this increases proportionately the work involved in their full use. In view of this, arrangements have been made with the Superintendent of H.M. Nautical Almanac Office to make the calculations for Satellites III., IV. here for the next issue, 1914. These are now in large part completed.

The remaining work of the Observatory has been confined to routine.

On November 28 Professor Sampson, who held the Chair of Astronomy in the University, with charge of the Observatory, was appointed Astronomer Royal of Scotland, in succession to Mr. Dyson. The Council of the Durham Colleges, with whom the decision rests, have not, so far, determined what is to be the future of the Observatory.

Glasgow Observatory. (*Director, Professor L. Becker.*)

In January the regular work with the spectrograph was interrupted, and attempts were made on every available evening to photograph the spectrum of Comet 1910 *a* with this instrument and with a prismatic camera of $3\frac{1}{4}$ inches aperture. From April 25 to May 15 a regular lookout was kept for Halley's Comet before

sunrise, but owing to cloudy weather and a hazy horizon the comet was seen on only two occasions, and then during a few minutes. At the end of May the comet appeared faint in strong twilight and could not be photographed.

The 7-inch refractor, presented by Mr. Cameron Corbett, M.P., some years ago, was housed in a canvas-covered dome, and is now used by students.

The time service and the meteorological observations have been carried on as in former years.

Liverpool Observatory. (*Director, Mr. W. E. Plummer.*)

The work of the Observatory has remained the same as in past years, and the astronomical equipment also has undergone no change. In connection with the Time Distribution Service and the testing of chronometers for the use of the mercantile marine, it may be mentioned that some attempts have been made to observe the time signals despatched by radio-telegraphy from the Eiffel Tower, Paris, and also from the Nordreich station. The signals were not received at the Observatory, since the necessary electrical installation was wanting, but the Observatory was in telephonic communication with the Government station at Waterloo. As the signals were received they were reported to the Observatory; and though such a process would be, of course, useless for accurate longitude work, it reproduced the conditions that might be expected to obtain at sea. The accuracy for longitude determination was found to be more than sufficient for navigation purposes. The equatorial has been used for the observation of comets and double stars, as in previous years.

It was mentioned in the last Annual Report that a second Milne Seismometer of unusual sensitiveness had been placed in the cellar of the Observatory, with the pendulum mounted in an azimuth 90° different from that of the original instrument. This instrument, on which the time scale was purposely reduced, was not well adapted for the registration of earthquakes, but by its increased sensitiveness it was admirably suited to measure the effect of a tidal load on the banks of the Mersey, and the consequent deformation of the Wirral peninsula. Some early results have been communicated to the Seismological Committee of the British Association. The pendulum has since been placed at different angles with the meridian, in order to determine the position best suited for a continuance of the observations.

Radcliffe Observatory, Oxford.
(*Director, Dr. Rambaut, Radcliffe Observer.*)

During the year 1910 the 24-inch photographic refractor has been chiefly employed in connection with the plan, described in former reports, for determining the proper motion of stars down

to the 14th magnitude. The progress of this work has, however, been much impeded by the very unfavourable weather which has for the most part prevailed. It has been further delayed by interruptions arising from the necessity of observing the comets for which the year has been remarkable. In connection with this proper-motion work, 51 plates, each representing two exposures, have been obtained.

The results of the observations of comets made at this Observatory have been communicated to the Society, and published in the *Monthly Notices*, lxx. p. 497, and lxxi. p. 133.

Miscellaneous photographs taken with this instrument include the cluster Messier 3 (Canes Venatici), exp. 1 hour, the Moon during the total phase of the eclipse of November 16, exp. 38 minutes, the region of the Pole, and others taken for instrumental adjustments.

The 18-inch refractor, when not in use as guider to the 24-inch photographic equatorial, and the 10-inch Barclay refractor, have been frequently used for observations of comets. The latter instrument also continues to be employed by Mr. Barrett for observations of the variable stars, RW and ST Draconis. During the year he has made 156 observations, distributed over 13 nights, of the brightness of the former star, and 18 observations on 17 nights of the latter.

During the eclipse on November 16 this telescope was employed in observing occultations of stars by the Moon. The results have been communicated to the Society (*M.N.*, lxxi. p. 142).

Last year the measurement of the parallax plates taken with the 24-inch refractor had to be discontinued in consequence of pressure of work in the meteorological department in preparing a new volume for the press. This work having been completed, the parallax measures were resumed towards the end of the year 1910, and are now being systematically carried on.

Tables for converting right ascension and declination into standard co-ordinates of a general character, equally applicable to all declinations, have been computed. These, as well as the formulæ on which they are based, have been communicated to the Society in a paper published in the *Monthly Notices*, lxx. p. 655.

In previous reports allusion has been made to Herr Osten's revision of Main's observations (made with the transit circle during the years 1862–1876, and published in vols. xxii. to xxxvi. of the *Radcliffe Observations*), on which he has been engaged for some years past, in connection with the *Geschichte des Fixsternhimmels*. This work has now been completed, and the result of Herr Osten's labours has been recently issued in a convenient 4to form, entitled by him *Dritter Radcliffe Katalog*.

The work of revision has been from first to last a labour of love on Herr Osten's part, and the catalogue which he has produced of 5808 separate objects, reduced to the system of the new Fundamental Catalogue of the *Berliner Jahrbuch*, ought to prove

a valuable compilation, as presenting Main's results, which are scattered through the annual catalogues of fifteen Radcliffe volumes, in a homogeneous and readily accessible form.

University Observatory, Oxford.

[Report inadvertently delayed: will appear in the March number of the *Monthly Notices.*]

Temple Observatory, Rugby.

The usual instruction in the use of instruments has been given to the senior boys, while the junior ones have been shown objects through the telescope. A few measures of double stars have been contributed to the Society and printed in the *Memoirs.*

Royal College of Science, South Kensington.
(*Assistant Professor A. Fowler.*)

As in former years, the instruments were chiefly employed for the instruction of students, and for observations of the spectra of sun-spots and metallic prominences. A report on sun-spot spectra was presented to the Fourth Conference of the International Solar Union at Mount Wilson. So far as they can be investigated with the instruments available, the spectra of spots have shown no marked variations since the observations were commenced in 1903.

The work of the laboratory was mainly directed to the possible elucidation of the outstanding features of cometary spectra. Further experiments have rendered it very probable that the low-pressure spectrum which reproduces the characteristic bands of the tails of comets (including Halley's Comet) has its origin in carbon monoxide, and additional faint bands belonging to this spectrum have been identified and measured. A new series of bands given by carbon monoxide at comparatively high pressures has also been detected, and this appears to give a satisfactory explanation of the abnormal appearances occasionally observed in the bands given by the heads of comets, as compared with the Bunsen-flame bands of carbon (*Monthly Notices*, lxx. p. 484).

A valuable addition to the equipment of the Observatory has been made by the erection of a 5-inch equatorial having a Zeiss triple object-glass and an objective prism of 45°. It is provided with an electrically-controlled clock, cameras for direct photographs at the principal focus and for enlarged photographs of the Sun and Moon, and other accessories, including a complete system of electrical illumination. The optical performance of the instrument is very satisfactory, and stellar spectra, extending over 3 inches from H_α to near the end of the hydrogen series, are

adequately focussed on a flat plate perpendicular to the optic axis. The mounting was specially designed by Sir Howard Grubb to embody some of the features usually only found in larger instruments, in order to better adapt it for purposes of instruction. An additional objective prism, of small dispersion, is in course of construction by Sir Howard Grubb.

Solar Physics Observatory, South Kensington.
(*Director, Sir Norman Lockyer, K.C.B.*)

Observations of Sun-spot Spectra.—The Sun was visible on 210 working days during 1910, and observations of sun-spot spectra were made on 57 days, 75 spots being examined in the F—*b* region. The chief widened lines are still those due to vanadium, titanium, magnesium associated with hydrogen, and scandium.

Spectroheliograph.—Attempts to secure photographs of the Sun in "K_{2-3}" light with this instrument were made on 147 days: 240 negatives showing the distribution of calcium flocculi were taken, and 206 of them have been selected for measurement and reduction. In addition to these, 68 "limb" negatives were obtained, thus securing a record of the prominences; on most of these an exposure was made on the disc as well.

In accordance with the arrangement made with the Indian Government, 363 spectroheliograms, showing the disc in "H" or "K" light, have been received from the Kodaikánal Observatory during 1910; these cover the period September 1, 1909, to September 30, 1910. Fifty-two glass positives of the Sun's limb in "K" light were forwarded from South Kensington to Kodaikánal during the year.

Areas of Flocculi.—The measurement and reduction to a uniform scale of millionths of the Sun's disc of spectroheliograms taken at South Kensington for those days in 1906 for which no record had been obtained at Kodaikánal have been completed, and measures have been made of the Kodaikánal plates to September 1907.

At present it appears inadvisable to include in the record measures of plates taken with spectroheliographs widely different from those at Kodaikánal and South Kensington. Later years show a decreasing number of days on which no photographs were obtained at either of the stations.

Sun Photographs.—Daily photographs (glass negatives) of the Sun's disc, taken with the photoheliograph, have, as usual, been received from Dehra Dûn. The Mauritius series of sun photographs terminated 1909 November 28.

Positives on paper are also received from Dehra Dûn, and these are mounted on cartridge paper and bound up in half-yearly volumes. Since the beginning of 1906 enlargements of spectro-

heliograms, when possible, have been mounted alongside the paper prints for comparison and ready reference.

Laboratory Work.—The experimental work has been chiefly devoted to the investigation of the chemical origins of lines in the spectra of celestial light-sources, more especially in connection with the spectra of the Wolf-Rayet stars.

Night Work.—Observers attended on 135 nights and photographs were obtained on 45 occasions. The 36-inch reflector with two-prism Hammersley spectrograph was in use until the mirrors required resilvering in August. Three negatives of the spectrum of the Orion nebula were obtained, and attempts were made to secure photographs of the spectra of Halley's Comet and of M. 64 Comæ Berenicis.

With the 6-inch Henry prismatic-camera with two 45° prisms 57 photographs of 19 stellar spectra were taken. Special efforts have again been directed towards extending the series of spectrograms of stars having peculiar spectra.

The 2-inch calcite-quartz spectrograph was dismounted during the early part of May and transferred to Fosterdown in preparation for observation of Halley's Comet. It was re-erected at the Observatory on June 9. Before and after this period it was employed for photographing the spectra of pairs of stars under identical conditions so far as possible, in order to compare their relative extensions into the ultra-violet; as a test of the relative apparent temperatures of the stars, twenty-four pairs of stars were examined during 1910. The 6-inch Dallmeyer camera, to which the calcite prismatic camera is attached, was also used at Fosterdown.

Halley's Comet.—Permission was obtained from the War Office to occupy the mobilisation centre at Fosterdown, near Caterham, a site selected by the Solar Physics Committee for the future position of the Observatory, and instruments for visual and photographic observations were sent there. In addition to the two mentioned above, a spectrograph of 9 inches aperture and 10 feet focal length, with objective prism of 45° angle, was erected on the same mounting.

Photographs of the comet and spectrum were obtained on May 22 and 26, and the results communicated to the Royal Society.

Solar Eclipse 1911.—Preliminary arrangements were made for the observation of the total solar eclipse of 1911 April 28, in the event of sanction being granted for the sending out of an expedition.

Publications.—Papers dealing with the Southern Hemisphere Surface Air Circulation, Researches on the Chemical Origin of various lines in Solar and Stellar Spectra, the Sequence of Chemical Forms in Stellar Spectra, and the Spectrum of Halley's Comet, have been published during the year. Other papers in connection with the Widened Lines of various Elements recorded in Sun-spot observations 1879–1908, and the Spectra of the Orion Stars, are nearly ready for publication, whilst papers on the Line absorption of α Orionis and the Northern Hemisphere Surface Air Circulation are in a forward state.

Stonyhurst College Observatory. (*Director, Rev. W. Sidgreaves.*)

The Sun's surface has been observed on 166 days, and 126 drawings made. On the remaining 40 days the surface was found free from spots. The mean daily disc area in units $\frac{1}{5000}$ the solar disc was 1·8 against 13·5 of 1909. The separate monthly means show a gradual rise from 0·2 in June to 4·4 in October, followed by a sudden drop to 0·2 in November and December.

The spectrographic study of the larger sun-spots, in the red and yellow regions, with the grating spectrometer, has been carried on as well as possible under the circumstances of unfavourable weather and other impediments.

Considerable interruptions of the work have been necessary for experimental preparation for the approaching total solar eclipse of 1911 April 28; and the finer period of our summer months was lost through the absence of Father Cortie as one of the delegates of the Royal Astronomical Society to the International Union for Co-operation in Solar Research at Mount Wilson; where, also, he presented a report on the spectra of sun-spots.

Father Cortie has accepted the invitation of the Joint Permanent Eclipse Committee of the Royal and Royal Astronomical Societies to take charge of the official expedition for the solar eclipse. He will be accompanied by Mr. Wm. M'Keon of this observatory. They will be stationed at Vavau, one of the Tonga group of islands in the South Pacific.

Halley's Comet and Comet 1910*a* were photographed, whenever possible, with the Whitelow 6-inch Dalmeyer portrait lens. But it was never possible to get a sufficiently long exposure for their spectra.

Wolsingham Observatory (*Rev. T. E. Espin*).

The examination of all the stars in the B.D. in certain selected zones, with a view to detecting new double stars, has been continued, and the zones $+50^\circ$ to $+55^\circ$ are now nearly completed. The results, together with the micrometrical measures of some other stars, have been communicated to the Society.

Mr. Franklin-Adams' Astrographic Laboratory.

The principal work undertaken during the year, both in England and at Johannesburg, has been the repetition of plates which have been rejected on account of imperfections. Many thousands of plates have been catalogued and stored, and various schemes for publication have been taken into consideration.

Mr. Newbegin's Observatory, Sutton, Surrey.

Fifty-eight solar observations were made during year 1910. 241 prominences were observed, yielding a mean daily average of 4·1. The southern hemisphere has been the most affected, but the balance is not so very much in its favour—approximately 7 per cent.

It may also be noted that the mean monthly average has fallen from 6·5 to 1 as between January and November.

A very large area in S. lat. 10°–20° was disturbed by a group of tiny spots in September.

Rousdon Observatory, Devon.
(Sir Wilfrid Peek's; C. Grover, Observer, in charge.)

The building is in good repair, and the astronomical instruments are in perfect working order. The electric light is now being installed, and besides lighting the ground floor, will be used to illuminate the dome and the circles of the equatorial. Weather was generally favourable, and observations were made on 144 nights. The best month was May, when observations were made on 23 nights. Observations of long-period variable stars with the 6·4-inch Merz refractor equatorial were continued exactly as in former years, and 299 magnitude determinations were recorded, making a total of 11,187 magnitudes during the twenty-five years this work has been in progress.

The great daylight comet (1910*a*) was first seen on January 21, so near the sunset horizon that it was visible for only a few minutes. The next night it was a fine naked-eye object, and rapidly increased in brilliancy. On January 30 the tail extended fully 25°, and remained visible nearly an hour after the head had disappeared below the horizon. It was last seen here, February 9, with the equatorial, being too faint to be visible to the naked eye.

Much attention was given to Halley's Comet, which was first seen here 1909 November 18, and was last observed travelling southward 1910 June 14, having been visible about seven months, or, more exactly, 204 days. Most of this time it was very faint with the equatorial telescope, and was first seen by the naked eye on a few mornings at the beginning of May. The comet was at no time a brilliant object in these latitudes, but was best seen in the evenings toward the end of May. On the 27th the comet was an interesting naked-eye object a little below Regulus; the tail lay nearly horizontal, and, though faint, could be traced 10° or 12°. Metcalf's Comet (1910*b*) was observed on August 12. It was merely a condensed nebulosity, with no signs of a tail, and was last observed here September 1, when it was very faint.

Observations with the transit instrument have been regularly taken for the regulation of the sidereal clock.

Rev. T. E. R. Phillips's Observatory, Ashtead, Surrey.

The 12¼-inch Calver equatorial has been used chiefly for observations of Comet 1910*a* and Halley's Comet, the planets Jupiter and Saturn, and the measurement of double stars. The last observation of Halley's Comet was on June 14, when, owing to moonlight, twilight, and proximity to the horizon, it appeared almost as faint as in 1910 November and December.

The meteorological observations have been continued.

Mr. Saunder's Observatory, Crowthorne, Berks.

Work has been continued on the two Yerkes plates of the moon. The reduction of the measures has been completed, and a catalogue giving positions of 2885 points has been presented to the Society. This will shortly appear in the *Memoirs*.

Kodaikánal and Madras Observatories.
(*Mr. C. Michie Smith, C.I.E., Director.*)

In spite of an unusually heavy rainfall, the year was, on the whole, a favourable one for solar work, and there were only 10 days on which no observations were possible.

Photoheliograms were taken on 345 days.

Sun-spots.—Observations on sun-spots were made on 355 days, and their positions were roughly determined by projection. The number of new spot-groups observed during the year was 152, with a mean daily number of 1·8 against 221 and 3·5 in 1909. There were 52 days on which no spot was observed, against only 4 days in 1909. Of the new groups observed, 105 were in the southern hemisphere.

Visual Spectroscopic Observations.—These were continued as in former years, but, owing to the great decrease in the average size of the spots, there were only 35 days on which satisfactory observations of spot-spectra could be made. Observations of metallic and eruptive prominences were made whenever possible.

Spectrographic Observations.—Numerous photographs of the H_α region in spot-spectra have been secured with the large spectrograph; these were obtained with a view to studying the movements of the higher chromosphere over spots. In nearly all spectra obtained the H_α line is found to be inclined over spots, the displacement being towards the violet on the side of the spot nearest the limb in all cases. This shows that the hydrogen moves radially inwards towards the spot centre, in opposition to the movement of the metallic vapours of the reversing layer. This inward motion had already been detected in the calcium of the

higher chromosphere, the H_3 and K_3 lines being similarly inclined towards the violet on the limb side of the spot.

A series of spectra of the H and K region in spots have also been obtained for the purpose of detecting and estimating vertical movements in spots and in the surrounding faculæ. Most of the plates obtained have been measured and reduced.

Prominence spectra have been photographed with a comparison spectrum of the centre of the Sun's disc. These plates are being measured to determine radial velocities at different heights above the Sun's limb.

A series of spectra of Halley's Comet were obtained with a prismatic camera attached to the south dome equatorial. Seven of the plates have been measured and reduced.

Spectroheliograph.—Photographs of the Sun's disc in K light were obtained on 335 days, and prominence plates on 290 days. The position angles and heights of all the prominences were measured, and comparison made with the visual observations.

Comets.—A number of observations were made of Comet 1910*a* while it was visible during daylight, but the evenings were unfortunately cloudy during the time that it was visible after sunset, and no photographs of it could be obtained. Halley's Comet was observed whenever possible between April 18 and May 30, and a fine series of photographs were obtained (see *Kodaikánal Observatory Bulletin*, No. xx.).

Publications.—Bulletins Nos. xix. to xxii. were published during the year.

The usual meteorological and seismological observations were continued.

At Madras the chief astronomical work was, as usual, the maintenance of the time service.

Adelaide Observatory, South Australia.
(*Director, Mr. G. F. Dodwell, Government Astronomer.*)

Sir Charles Todd, for more than fifty years Government Astronomer of South Australia, died on January 29th, 1910. An account of his work as Director of the Observatory appears amongst the obituary notices published by the Council. His death is a great loss to the Observatory, as, although he had retired from active service in December 1906, his unabated interest in astronomy and his advice and helpful influence were of the greatest value.

Mr. W. R. Browne, who has graduated in Science at the Sydney University with double first-class honours (Mathematics, including Astronomy, and Geology), was appointed First Assistant in February, and is a welcome addition to the staff.

The early part of the year was occupied with preparations for observing the total solar eclipse of May 9 in Tasmania. A party from Adelaide joined the Australian expedition, which was under the leadership of Mr. Baracchi, Government Astronomer of Victoria.

The Adelaide Observatory representatives were the Director and Mr. Browne. Mr. A. W. Dobbie, J.P., of Adelaide, co-operated, and took his two 12-in. concave mirrors, used in a special combination. At Bruni Island, the site chosen for the camp, the eclipse was unfortunately totally obscured by clouds, but some interesting observations were obtained by amateur observers at Queenstown. A report to the South Australian Government on the eclipse has been published.

The time service has been continued as usual and the time-ball at the semaphore dropped daily at 1 p.m., with only a few failures due to temporary defects in the telegraph circuit.

A regrettable delay has been experienced in making the improvements to the transit circle telescope which were thought necessary or advisable before commencing systematic observations of the *étoiles de repère* in the zone $-20°$ to $-30°$. The work has been in hand for some time, however, and the essential parts are nearing completion. One of these alterations is the substitution of ball-bearing collars at the ends of the axis, instead of the friction roller supports formerly in use.

A determination of the pivot errors of the transit circle has been made, and shows that the pivots are in good condition, though the errors are sufficiently appreciable to need correction.

A series of experiments for determining the flexure of the telescope in any position has been made. These experiments are not yet complete, but in the course of the work some interesting results as to the effect of the heat of an electric lamp held near the telescope tube were obtained. A very marked flexure, as much as $2''{\cdot}5$, was produced in a short time, and suggests that the effect of the temperature of the observer's body on the instrumental flexure, especially in cold weather, ought not to be neglected.

The Director paid a visit to the Perth Observatory in September in order to confer personally with Mr. Cooke with regard to the latter's scheme of zone observations, and to inspect the various labour-saving devices and instrumental improvements which have been adopted at Perth.

During the year a photographic attachment to the 8-in. Equatorial was constructed by Messrs. Cooke & Sons of York, and has been made use of for solar and other photographs. This is in default of a proper photographic equipment, which would be very advantageous in the clear skies of Adelaide.

With the equatorial, observations of Halley's Comet were made during the first half of the year. The dome was put into electric connection with the transit-room, so that the beats of the standard sidereal clock are now chronographically recorded in both rooms.

The seismograph has been continuously at work during the year, and the records are sent to Professor Milne for examination and publication.

The mean-time clock has been fitted up so as to give an

electric signal hourly, and has been connected with the seismograph, thus replacing the driving-clock of that instrument as a time marker.

The custom of admitting the public to the Observatory one evening each week has been continued; the usual monthly lecture on Astronomy at County Institutes has also been continued.

In addition to the report on the Tasmanian eclipse, the following minor publications have been issued:—(1) South Australian Earthquakes. (2) The Cooke Sun-Dial. (3) Brief account of the Adelaide Observatory. The latter was issued as a bulletin of the Intelligence Department.

Some buildings at the Observatory not required for astronomical purposes have been leased to the Commonwealth Government for the use of the Meteorological Bureau, and the meteorological observations at the observatory have thus been continued as heretofore by the Commonwealth officials.

Melbourne Observatory. (*Director, Mr. P. Baracchi.*)

8-*inch Transit-circle.*—The following observations have been made:—

	R.A.	N.P.D.
Clock stars	1048	196
Azimuth stars	377	121
List stars	117	116
Auwers' fundamental stars	1179	1177
Stars for magnitude equation	434	12
Miscellaneous (comparison stars for Eros and Halley's Comet)	47	63
Total	3202	1685

Observations for Instrumental Errors:—

Collimation	178
Level	236
Nadir	184
Flexure	12

Reductions.—The Annual Catalogue for 1909 has been completed. The observations made in the year 1910 have been reduced to apparent place, and the reductions to mean place are well advanced.

In the preparation of the catalogue for the epoch 1900, containing the Astrographic Standard Stars which have been observed at least three times, all stars as far as 23h. have been reduced to the epoch 1900, and the precessions and secular variations computed.

The total number of stars included in this catalogue is 7000,

but it is intended to increase the original list by about 3000 stars, which will bring the average number of stars to 4 per square degree of the Melbourne Zones.

Astrographic Telescope :—

	Number of Plates obtained.
Catalogue plates, Series I.	26
Do. Series II.	6
Chart plates, triple exposure of 30^m each	66
Plates for special objects (comets, etc.)	11
Oxford chart regions	13
Pole plates	49
Plates for adjustment	13
Rejected	36
Total	220

Measurement of Plates :—

Sydney Zones: 67 plates, containing 46,995 stars, were measured.
Melbourne Zones: 38 plates, containing 24,094 stars, were re-examined and re-measured.

Good progress has been made in the computation of standard co-ordinates and plate constants.

Voigtlander Photographic Doublet, 6-inch clear aperture and 42-inch focal length.—A mounting for this lens was constructed in the Observatory workshop early in the year, and was rigidly attached to the 4-foot reflector. It was used for photographing Halley's Comet, of which 14 plates were obtained, in addition to many experimental plates required for adjustment.

8-inch Equatorial.—Observations of Comet Cerulli were made on 9 evenings, using a square bar micrometer.

The Time Service for the State of Victoria and all other routine duties for the service of the public have continued to form a considerable part of the programme of this Observatory.

The weather of the year 1910 was exceptionally unfavourable for astronomical observations. There were only 72 nights from January to August and 25 from September to December upon which satisfactory work could be done.

The Total Eclipse of the Sun of 1910 *May* 9.—An expedition was organised for observing this eclipse.

The site selected was at Alonnah, on Bruni Island, some 30 miles south of Hobart. Parties from the Sydney University, from the Adelaide Observatory, and from New Zealand joined the camp.

Some 26 observers stood at their post at the time of the eclipse, but the day was cloudy and wet, and the expedition failed in its main object.

An accurate determination of the longitude of the camp was,

however, made by direct exchange of time signals telegraphically between the Transit hut at Bruni and the Melbourne Observatory on 4 nights.

The longitude of the transit pier was found to be 9h. 48m. 59s·18.

Perth Observatory, Western Australia.
(Director, W. Ernest Cooke.)

Meridian Observations.—Good progress was made in this branch. The complete Zone 35°–37° was observed and reduced, thus forming a record for this observatory. Precessions and proper motions are now being computed, and the manuscript will soon be ready for the printer. It will form vol. v., and is expected to be published in a few months. These five volumes comprise the *étoiles de repère* between 31°–37° and 39°–41°, also the "intermediate" stars for the whole region 31°–41°. Vol. iv. was published and distributed during the year.

Astrographic Catalogue.—On comparing the number of stars measured on the plates in Zone 31°–33° with the C.P.D. it was found that the ratio Perth : C.P.D. varies considerably for different plates. This may be due to a want of uniformity in either or both sets of plates, and there seems to be no satisfactory independent criterion. It seems a pity to just go ahead and measure and publish results without some attempt to secure uniformity in the magnitudes, so a number of experiments have been made. Eventually the following plan was adopted and carried out between 18h and 24h R.A. for the plates with centres at 32°. With an ordinary clear night the 11th magnitude stars in Pritchard's regions just show a perceptible image with an exposure of 2m if the development is carried to its limit, so that the plate *just* commences to fog all over. Therefore in each evening's set of plates one or two Pritchard regions are included, and all the plates are exposed for 4m, 2m, and 13s. The temperature of the developer and washing water is reduced with ice when necessary to 65° F. or less, and development is carried to the first appearance of fog. As a guide, a series of little squares of different thicknesses of tissue paper are pasted along the edge of the *réseau* plate, and the gradual appearance of these squares not only assists in estimating the length of development required, but forms a permanent record of its extent. As soon as the plates are dry the Pritchard region is first examined. Three points are specially noted. It should show a certain (average) total number of stars : the 9th magnitude stars should give a certain ascertained diameter or appearance, and the 11th magnitude should just show nicely. If in any respect this plate is unsatisfactory, all those taken on the same evening are rejected. If Pritchard is accepted, the other plates are counted, and ratios with C.P.D. formed. These should on the whole be between 2 and 3, and if any individual plate shows a large abnormality it is temporarily rejected and retaken if possible. The

new set of plates between 18^h and 24^h R.A. have all been measured and will be the adopted ones, but for the future those plates that have already been measured will be accepted whenever the count is reasonably near the adopted criterion. All this work has delayed publication, but progress will now probably be again steady, and it is hoped that the first volume may be published some time before next July.

Visitors.—The Institution is becoming increasingly popular, and now five evenings per month are regularly given over to visitors, in addition to others in special circumstances. This interferes considerably with the routine work, since the staff is small; and its effect is becoming apparent in the plate constants. Whenever visitors are expected the "working" eye-end of the guide telescope is taken off and a more suitable eyepiece substituted. Those who have used a valuable instrument in such a manner, and who have experienced the craving of the visitor to turn screws, will easily understand that the "*c*" and "*f*" of the plate constants are frequently large, and that the "*a*" and "*e*" vary from time to time, owing to slight displacements of the focus. The Government has now authorised the purchase of a 12½-inch reflector for visitors, and when this is received the astrographic work will be more satisfactory.

Time Service.—The time-ball at Fremantle failed on eighteen occasions, all but one failure being due to faults on the line, or causes beyond the jurisdiction of the observatory. Otherwise it dropped regularly at 1 p.m., and at such other hours as were required by the Chief Harbour Master. The mean of all the recorded times of ball-drop was $1^h\ 0^m\ 0^s{\cdot}02$.

The following is a *résumé* of the work done during the year:—

Plates completely measured in direct and reversed positions	66
Number of stars measured	31,774
Plates taken (including 56 of Halley and 6 Solar Eclipse)	276
Nights on which time was determined	216
Observations of clock stars in R.A.	1057
,, ,, zone ,, ,, ,,	6436
,, ,, ,, ,, ,, N.P.D.	6436
Separate determinations of Collimation error	6
,, ,, Level ,,	199
,, ,, Azimuth ,,	123
,, ,, Nadir point	166

Sydney Observatory.
Mr. W. E. Raymond, Officer in charge.

The weather during 1910 was, on the whole, more favourable than that of the year 1909, and a good number of observations were made. The transit meridian circle has been in use through-

out the whole of the year on the time service, and also observing the stars for the Astrographic Catalogue.

The 11·5-inch equatorial telescope, under Mr. W. E. Raymond's charge, has also been constantly employed on comet observations and double-star measures.

The number of observations of R.A. of stars totalled	. .	1637
,, ,, N.P.D. ,, ,,	. .	966
,, ,, R.A. of Sun ,,	. .	453
9 a.m. Collimation, Level and Nadir observations	.	305 of each
9 p.m. Level and Nadir observations	. . .	84 ,,

Azimuths determined from 84 pairs of circumpolar stars.

With the 11·5-inch refractor telescope 103 pairs of double stars were measured, and 27 observations of Halley's Comet were also made.

The Astrographic work was continued under Mr. J. W. Short at the Red Hill Branch Observatory at Pennant Hills. The plates taken comprised 111 chart plates, 12 catalogue plates, 4 Oxford test plates; and in addition, 33 plates were exposed on other objects, principally Halley's Comet. For magnetic declination and intensity, 44 and 10 observations were made respectively.

Mr. W. C. Graham, in addition to his usual work, has had charge of the Milne seismograph, and during the year has recorded 168 Earth tremors, being an increase of 6 per cent. over those of the year 1909. All the tremors he has measured and tabulated; and the reports, together with notes of the principal disturbances, and copies of the same, have been forwarded to the Seismological Committee of the British Association, London.

Mr. W. I. Masters, mechanician, has had charge of the instruments, and his duties have been carried out as heretofore. In addition, he designed and made the clock and several parts of the instrument intended for use by Mr. Short at the solar eclipse in May last.

Mr. P. P. Olden, with the assistance of Mr. H. Cranney, has carried on the transit work during the year.

775 visitors have registered their names during 1910, of whom 233 attended during the evenings for short lectures on celestial objects.

The principal event in connection with the Australian Observatories during the past year was the total solar eclipse of May 1910. The line of central shadow touched the south coast of Tasmania, and parties from the different Observatories, in addition to a private party from England, journeyed there to make observations. The Sydney Observatory was represented by the astronomical photographer, Mr. J. W. Short, who was attached to the English party. Unfortunately the Sun was completely obscured during the time of the eclipse, and no observations of the phenomenon were recorded.

Considering that the positions of Government Astronomer and

Astronomical Assistant are still vacant, the progress of the work during the year has been very satisfactory, and thanks are due to the members of the staff, by whose energies this result has been obtained.

Mr. Tebbutt's Observatory, Windsor, New South Wales.

The only astronomical work done during the year 1910 consists of micrometrical observations of Halley's Comet with the 8-inch equatorial. In addition to the observations of December 3, 4, 5, and 6, 1909, referred to in the last brief report, positions were secured on January 1, 2, May 25, 26, 29, 30, 31, June 4, 5, 7, 8, 12, 13, 25, 27, 30, and July 1, 1910. These positions, with remarks on the length of the comet's tail, have been forwarded to the Society for publication. No trace was seen of the comet's expected transit across the Sun's disc.

The annual meteorological observations were taken during the year.

Lovedale Private Observatory, South Africa.
(*Dr. Alex. W. Roberts.*)

During the year 3200 observations of variable stars were obtained. These were not taken in the systematic manner followed in most former years. They were rather in the direction of filling up gaps or of supplementing uncertain information. Special attention was paid to the variation of S Aræ and K Pavonis, as these stars show evidence of possessing characteristics both of short-period variation and Algol variation; that is, they exhibit variation due to eclipse, superimposed upon the ordinary Cepheid type of continuous light change.

The reduction of all observations made during the past twenty-one years is now practically complete. This will allow future work in the direction of examining photometrically those stars that are known to be spectroscopic binaries. In the southern hemisphere research of this character holds out a promising field of inquiry.

Transvaal Observatory. (*Director, Mr. R. T. A. Innes.*)

As the Transvaal Observatory now appears for the first time in the Society's Proceedings of Observatories, a few words on the history of its development may be given. Established in the year 1903, the Observatory was at first a purely meteorological one, and was entirely without any astronomical equipment until 1907. In September of that year a 9-inch refractor by Grubb was erected under the circumstances mentioned in the *Monthly Notices*, vol.

lxviii. page 32 of 1907 November. In 1908 the object-glass was taken to Europe, and retouched and much improved by Sir Howard Grubb. In 1908 and 1909 this telescope was mainly employed in the discovery of double stars and observations of the phenomena of Jupiter's satellites. In 1909 the equipment was increased by the gift to the observatory from Mr. J. Franklin-Adams of his 10-inch triple O. G. Cooke Star-Camera, which has a focal length of 45 inches. In the same year the Hon. J. B. Rissik (now Administrator for the Transvaal—then Minister for Lands) authorised the purchase of a 26-inch refracting telescope, for which a contract has been placed with Sir Howard Grubb. In 1906 Dr. Oskar Backlund was good enough to lend the observatory a universal instrument ($2\frac{3}{8}$-inch object-glass) by Bamberg, to be used for observations of latitude.

Sir David Gill, who is supervising the construction of the 26-inch refractor, reports good progress with the mechanical parts and the delivery of the Repsold micrometer, but, so far, M. Mantois has not succeeded in casting suitable discs for the object-glass. The building for the telescope is now ready for the dome and floor.

The Franklin-Adams Star-Camera has been engaged during the greater part of the year in completing the charts of the southern hemisphere required by Mr. Franklin-Adams, and for this purpose has been in the hands of his Assistant, Mr. R. J. Mitchell. During its apparition a series of photographs of Halley's Comet was taken by Mr. H. E. Wood, 50 plates being secured.

The 9-inch refractor has again been used for observing the phenomena of Jupiter's satellites and the discovery of double stars—the number of the latter discovered with this telescope now exceeds 600; and by Mr. W. M. Worssell for variable stars which are too faint for his own 4-inch refractor. Numerous drawings of the nucleus of Halley's Comet were made with this telescope.

Observations for the variation of latitude with the Russian instrument were commenced in March under the auspices of the *Central Bureau der Internationalen Erdmessung*, which supplies the star-places and reductions to date. The Bureau shares in the cost of the work here.

In 1910 it was determined to issue circulars containing the results of the observations made. The informal nature of these circulars lends itself to easy and early publication. So far, five circulars have been issued, and a sixth is in the Government printer's hands.

Besides the astronomical work, the staff undertakes time-service and meteorological and seismological observations.

Notes on some Points connected with the Progress of Astronomy during the Past Year.

Discovery of Minor Planets in 1910.

Forty-three new planets were discovered or first announced in 1910.

Letter.	Date. 1910.		Discoverer.	Letter.	Date 1910.		Discoverer.	Letter.	Date. 1910.		Discoverer.
JH	Jan.	7	W	JY	Mar	30	H	KN	July	12	H
JJ		10	M	JZ		15	M	KO		14	H
JK		31	W	KA	Apr.	13	M	KP		14	H
JM	Feb.	2	W	KB		27	D	KQ		16	H
JO		14	H	KC	June	3	H	KS	Sept.	10	E
JP		1	M	KD		5	H	KT	Oct.	3	P
JQ		2	M	KE		5	H	KU		2	C
JR		4	M	KF		5	H	KV		6	E
JS		4	M	KG	May	6	M	KX		9	H
JT		7	M	KH		6	M	KY		3	M
JU		7	M	KJ		6	M	LA	Nov.	8	C
EK[a]	Oct.	21 *	M	KK		6	M	LB	Oct	28	M
JV	Feb.	28	H	KL		6	M	LC		28	M
JW	Mar.	4	H	KM	Mar.	3	B	LD	Dec.	22	W
JX		5	H								

* 1908.

JZ was subsequently found on Heidelberg photographs of March 9 and 14.

The initials stand for: B = M. Baillaud (Paris); C = Dr. Cerulli (Teramo); D = Mr. Davidson (Greenwich); E = Herr Ernst (Heidelberg); H = Herr Helffrich (Heidelberg); M = Dr. Metcalf (Taunton, Mass.); P = Dr. Palisa (Vienna); W = Professor Wolf (Heidelberg).

The planet named HL is identical with 138 Tolosa, JL with 294 Felicia, JN with 273 Atropos, KR with 216 Cleopatra, KW with 42 Isis, KZ with 62 Erato.

The following planets not numbered at the date of the last Report have since received permanent numbers: DU 675, FN 676, FR 677, FS 678, FY 679, GW 680, GZ 681, HA 682, HC 683, HD 684, HE 685, HF 686, HG 687, HH 688, HJ 689, HZ 690, JG 691; DC, EJ, HN, JA, also 1901 HD, will subsequently receive permanent numbers.

The following planets have been named: 659 Nestor, 671 Carnegia, 679 Pax, 687 Tinette, 688 Melanie, 690 Wratislavia, 691 Lehigh, KU Interamnia. A. C. D. C.

Comets of 1910.

Two comets were visible at the beginning of last year. One of these, Daniell's (1909*e*), was last seen at Algiers on March 15, but was photographed a month later by Professor Max Wolf at Heidelberg. The calculation of the definitive orbit has been undertaken by Dr. Krassowski, but the period will not differ greatly from 6·4 years. The other comet under observation was Halley's (1909 *c*), which is still visible in large telescopes, though the last published observation is dated December 7. The object is described as of the 14th mag., and the decrease of light will probably be very slow. This comet was observed in every observatory, public and private, and its return has produced an abundant literature; it is impossible to give here any useful analysis of observations so extensive and varied. This is the less necessary as a monograph is in course of preparation by a committee of American astronomers, which will be the authoritative source for information, aiming, as it does, at the exhibition of the history of the comet's variations from hour to hour. But, apart from the mass of observations, visual, photographic, and spectroscopic, that have been collected, an interest, distinct from that attaching to all bright comets, has centred around a few points to which reference must be made. First, the possibility of seeing the comet projected on the Sun. It is known that the centre of the comet was projected on the Sun's disc, but, notwithstanding some reported observations, it is doubtful if the comet was seen. It has been suggested that the comet, having a parallax of nearly a minute, would subtend an angle sufficient to include the Sun's disc. Another point which caused great excitement was the possibility of the Earth passing through the tail of the comet. If the tail were simply a prolongation of the radius vector, the question might be easily settled; but since the tail is shown to be of a very complex structure, spreading out as a fan, this question can only be settled by observation. Many observers have reported unusual atmospheric conditions, but whether such phenomena were traceable to the presence of Halley's Comet is very doubtful. It seems certain that the Earth did not pass through the more conspicuous portion of the tail, and equally probable that it did encounter some of the outlying fan-like extensions. Professor Birkeland suggested the possibility of magnetic disturbances being noticed if, as he supposed, the tail were formed of electrical corpuscular rays. He himself reported a magnetic storm, though no very decided fluctuations were seen at other observatories. Auroræ were seen in several observatories in America, but again there is no proof of any physical connection between these and the comet. Similarly with meteors: though a stream whose members are seen in the first week of May has been suggested as connected with Halley's Comet, no decided proof of connection is forthcoming, nor were more meteors seen than in other years. Many other

suggestions were made at the time the comet was increasing in brightness,—evidence of public excitement and of scientific activity, but of little practical service.

Comet 1910 *a*. In the middle of January a bright comet was seen in South Africa, and the first accurate observation appears to have been made by Mr. Innes at Johannesburg on January 17, when it was near to the Sun. The comet was moving rapidly northwards, and was very generally observed in Europe after the 20th. The comet was conspicuous owing to its tail, which was at its best 50° in length, and had much the appearance of that of Coggia's Comet in 1874. The spectrum of the nucleus resembled that of Comet Wells in 1882, in which the sodium lines shone with great brilliancy. By March the comet was too near the Sun for observations to be continued in this country. A great interest attaches to the orbit, or rather to the difficulties of determination it presented to the computer. Want of accuracy in the observations, due to the comet being low down on a bright sky, on which comparison stars could not be seen, explains some of the difficulties encountered, but Tscherny has shown that Lambert's equation could be satisfied by three values of the curtate distance at the first observation, with no criterion to determine the selection. Such cases do not seem particularly rare, but in this instance the difficulty was aggravated by the small perihelion distance, about $\frac{1}{10}$ R, so that the comet would pass over a large arc of anomaly in the first few days of observation. The orbit is probably parabolic, but an ellipse of 200 years' period has been assigned.

Comet 1910 *b* was a faint comet, discovered by Metcalf on August 8, distinguished by rather large perihelion distance and small geocentric motion. The comet is probably still under observation, having been seen at Algiers on 1910 December 6, when it was reported to be of the 12th magnitude. The orbit is probably parabolic.

Comet 1910 *c* is a return of D'Arrest's Comet, found by M. Gonnessiat in Algiers on August 26, who described it as an object of 2′ or 3′ in diameter, with a feeble central condensation of the 14th mag. The corrections to the ephemeris of M. Gustave Leveau, whose researches on the motion of this comet are well known, are comparatively slight, and can be removed by a slight diminution in the mean motion, making the time of perihelion passage 0·4 days later than the calculated time. The discovery of the comet and the closeness of the prediction are the more satisfactory, as the comet was not seen at its last return towards the close of 1903.

Of Comet 1910 *d* (Brooks) the perihelion passage really takes place this year, but the comet was happily found by Professor Aitken on September 28, and very close to the predicted place. The perturbations were calculated by Dr. Neugebauer from elements computed by Dr. Bauschinger, who reports that he has not been able to combine in one system the observations of 1889, 1896, and 1903. His elements were founded on the last two apparitions,

and the closeness of the prediction shows that the selection was warranted.

Comet 1910 *e*. On November 9, Dr. Cerulli of Teramo discovered a tolerably bright telescopic comet, which for some time was observed as unknown. As soon as the elements were determined, the similarity with those of Faye's Comet was at once apparent. There was no reason for any confusion, for the place of Faye's Comet was approximately known, although no ephemeris had been prepared. The last calculation of perturbations had been made by Dr. Strömgren for the 1903 apparition, when the comet passed through perihelion without being seen. Dr. Strömgren showed that in 1899 the comet approached Jupiter within half the Earth's distance from the Sun; and as the two objects were travelling approximately with the same velocity in the same direction, the comet would remain so long under the influence of Jupiter that very considerable alterations would be introduced into the orbit. As a matter of fact, the return to perihelion in 1903 was accelerated four and a half months, making the chances of observation very slender. That Dr. Strömgren's work was very exact is shown by the fact that although no perturbations have been applied to his 1903 elements, they represent the path of the discovered comet, requiring no more alteration than about + 9 days to the date of perihelion passage. On the occasion of the 1896 return, when also no perturbations had been computed, the correction to the date of perihelion was + $7\frac{1}{4}$ days. The other elements show but slight differences between the unaltered work of Strömgren and the calculations from recent observations.

Spitaler's Comet, 1890 VII., has not been seen. It probably passed through perihelion in the middle of October. Measures have been taken to secure early observations of Westphal's Comet of long period, but it will probably not be seen until 1912.

Definitive elements of the following comets have been published during the year:—

Comet.	Character of the Orbit.	Calculator.	Authority or Source.
Comet 1883 II.	Elliptical	Moravi	*Ast. Nach.* 4400
,, 1904 II.	Hyperbolic	Sedlacek	,, ,, 4453
,, 1908 I.	Parabolic	Matkiewitch	,, ,, 4411

This last was the comet observed by Dr Max Wolf under the impression that it was Encke's. W. E. P.

The Orbit of Halley's Comet.

The award of the Lindemann prize by the *Astronomische Gesellschaft* to Mr. Cowell and Mr. Crommelin for their essay on Halley's Comet* has been cordially welcomed by astronomers.

* Essay on the Return of Halley's Comet, by P. H. Cowell and A. C. D. Crommelin. Lindemann Prize Essay. *Publikation der Astronomische Gesellschaft*, xxiii.

All recognise the simplicity of the theoretical principles involved, and the precision of which the method admits in the hands of its most capable authors.

The memoir is principally concerned with the solution of the following gravitational problem, where the astronomical unit is the unit of length, $+x$ is the axis towards the first point of Aries, $+y$ is towards longitude 90°, and $+z$ towards the north pole of the mean ecliptic of 1835 November 16·0. The date of perihelion is 1835 November 15·9453637, Paris M.T.

"A particle whose co-ordinates on 1835 November 16·0 and 1835 November 18·0 are as follows (referred to the centre of gravity of the Solar System),

Day.	x.	y.	z.
0	+0·311082620	−0·471220200	+0·167061003
+2	+0·259146677	−0·506048643	+0·159779449

moves under the attractions of the Sun, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. It is required to trace its motion forwards to 1910, and backwards to 1759."

It is obvious that the solution of this, as of any similar problem depending upon the solution of three differential equations of the second order, must contain six arbitrary constants. Three of these constants are the co-ordinates of the position of the particle at Paris mean noon on 1835 November 16. But it is in the selection of the other three constants that the new departure is presented. They are the co-ordinates of the particle two days later, *i.e.* at Paris mean noon on 1835 November 18. Thus the two rows of quantities just given are the six arbitrary constants of the problem in its first stage.

To find the co-ordinates of the comet on the date 1835 November 16·0, and 1835 November 18·0, it was necessary to know with accuracy the elements of the orbit of the comet at the 1835 return. From the observations made during that return it was possible to determine all the elements of the orbit except the mean motion. This could only be ascertained with sufficient accuracy after a calculation of the perturbations during the preceding revolution from 1759–1835. Hence the necessity that the computation should extend over two complete revolutions.

The prediction of the return in 1910 was the result of a series of steps of which we can here only give the merest outline. It was first necessary to compute the attraction of the Sun and each of the planets on the particle at the epoch 0·0 day (1835 November 16·0) and also for 2·0 day (November 18), and then by mechanical quadratures the position of the particle is ascertained at 4·0 day (*i.e.* 1835 November 20·0). The process is then repeated, the co-ordinates at 2·0 days and 4·0 days being now the arbitrary constants. The forces are calculated for 4·0 days, and again the mechanical quadratures will give the position of the particle at 6·0 days. By repetitions of the same process the path of the comet is built up by the portions of the trajectory traversed

in successive intervals of 2 days. No change is made in the process until 32 days have passed. The distance of the comet from the Sun has by this time become sufficiently great to permit the use of longer intervals than 2 days between the steps. From 32 days onwards the forces are calculated for the positions attained by the comet after intervals of 4 days. Thus the orbit of the comet is further built up arc by arc until 80 days after 0·0 day, which it will be remembered is almost the same as the time of perihelion. The continuous slowing down of the comet allows the intervals to be again doubled, so that between 80 days and 160 days from the start each of the intervals is a period of 8 days. The same process of doubling the interval is repeated at convenient stages until the interval has become 256 days, and the particle has then moved for 2560 days from perihelion. From this date onwards throughout the rest of the orbit the intervals remain at 256 days until the next perihelion passage is approached. Thus the complete path of the comet is built up by successive arcs, and the calculations have been carried on for 27,072 consecutive days since the return in 1835.

The dependence of accurate prediction of the return of the comet upon careful calculation of the attractions of the planets may be seen from the following facts. The comet completed one circuit between March 1759 and November 1835. If, therefore, there were no planetary interference and the same orbit was to be traversed again, the return to perihelion would not be due until July 1912, *i.e.* 27 months later than the actual return. The attraction of Jupiter alone has accelerated the recent return by no less than 800 days, which Mr. Cowell explains as follows:—"This is because the comet passed close to Jupiter at its return in 1835, which caused an acceleration of its motion. A close approach on one occasion makes the next return more difficult to predict. The former return is so nearly accomplished that it is too late to affect that greatly."

The accuracy of which the method is susceptible and the precision with which the calculations were carried through demand the highest admiration. When it was found that the time of perihelion predicted by Cowell and Crommelin was actually within three days of the true time, as subsequently observed, it was not unreasonably thought by many that the prediction was wonderfully close. But it is important to note that the character of the work demands a far higher appreciation than this would suggest. It is certain that an error of nearly three days could not have arisen in the calculation of the known causes of disturbance by the present method. The masses and positions of the planets are determined too accurately to admit this possibility. Suppose, for example, it were sought to remove the discrepancy of 2·7 days by admitting that an erroneous value of the Earth's mass had been used, Mr. Cowell has shown that an error of ten per cent. in the Earth's mass would be required, and this is twenty times the greatest error possible in the assumed value of that mass.

If all the forces in action on the comet were known, the cumulative errors of calculation in the work of Cowell and Crommelin could not produce an error of more than a fraction of a day in the predicted time of perihelion. But there is a discrepancy of 2·7 days, and we can only conclude, in the words of one of the authors of this remarkable essay, that "There is some small disturbing cause at work whose character is not yet recognised."

R. S. B.

Tables of Jupiter's Satellites.

The publication of Professor Sampson's Tables of the Four Great Satellites of Jupiter marks the conclusion (except for the publication of his theory) of a very great task. In the place of antiquated tables of no value, except as directing an observer when to go to his telescope, astronomers now have precise formulæ with which the observations of the future will naturally be compared. The precision arrived at in the formulæ corresponds to $0^s{\cdot}1$ in the times of the phenomena. This advance has materially added to the extent of the tables, and (for instance) it takes Professor Sampson three large pages of print to explain (without, however, giving quite every figure) how to calculate the phenomena of the first satellite comprised within one synodic period of $1\frac{3}{4}$ days. His results, compared with those given in the Nautical Almanac, are as follows:—

First Satellite.

	Sampson.	Nautical Almanac.
	d h m s	h m s
Oc. Dis.	1909 June 1 6 0 28·3	5 59
Tr. Ing.	2 3 22 1·4	3 18
Sh. Ing.	2 4 36 48·8	4 35
Tr. Eg.	2 5 37 8·9	5 38
Sh. Eg.	2 6 50 58·5	6 53
Ecl. Re.	3 4 2 32·2	4 0 53

The Nautical Almanac Office results are all obtained in one fifth of a MS. page, so that it will be observed that the use of Professor Sampson's tables will be a costly luxury.

A wrong formula unhappily crept into a portion of the tables, but has been already eliminated, and fresh tables substituted where necessary.

The author, it is to be regretted, has not seen his way to arrange the tables for serial work. He has left it to others to discover, for example, to what extent the cost of calculating the two hundred shadow ingresses of the first satellite that occur in a year may be reduced below two hundred times the cost of calcu-

lating one. The labour-saving devices that Professor Sampson might have found for serial work would probably have been better, owing to his more complete mastery of the subject, than the devices that several persons are probably already attempting to evolve independently; and there is, moreover, the waste of duplicate work that might have been avoided. P. H. C.

Solar Parallax.

Since the last Council note on this subject a great deal of work has been done by way of reducing the observations to which that note referred—the observations of Eros during the opposition 1900–1901. The first complete account of a set of observations was published in 1908 in the *Greenwich Observations* (appendix to *Greenwich Observations*, 1905). A very careful and detailed discussion of photographs taken with the Thompson and Astrographic equatorials led to the final result for the solar parallax of $8''{\cdot}800 \pm 0''{\cdot}0044$. Preliminary accounts of the determination of the solar parallax have also been given by Dr. Perrine from photographs taken at the Lick Observatory with the Crossley Reflector (*L.O. Bulletin*, No. 150), and by M. Perrotin from micrometric observations made at Nice (*Comptes Rendus*, vol. cxxxv. p. 881). Mr. Hinks (in a series of papers in the *Monthly Notices*) followed up a preliminary discussion of the Cambridge photographic observations with a complete discussion of the results obtained in accordance with the international programme of the Astrographic Congress, Paris, 1900. His final results, communicated to the Paris Academy, and recognised by the award of a prize from the funds of the *Fondation Leconte*, are—

$\pi = 8''{\cdot}807 \pm 0''{\cdot}0028$ from the photographic measures
and $\pi = 8''{\cdot}806 \pm 0''{\cdot}004$ from the micrometric measures,

while the mass of the Moon $= 1/(81{\cdot}53 \pm 0{\cdot}047)$, (*Monthly Notices*, vols. lxix., lxx.). This value of the solar parallax may be taken as definitive so far as the complete set of observations of this opposition are concerned.

The enterprise thus brought to a conclusion had its origin at the Paris Astrographic Congress of 1900, which appointed a Commission to organise co-operation in the observation of the planet Eros at the then forthcoming opposition. The Commission drew up, in general terms, a programme of work, and then practically, if not formally, resigned its functions to one member, the President of the Permanent Committee and Director of the Paris Observatory, the late Maurice Loewy. To his energy and influence the eventual success of the enterprise is due in very great measure. The series of "circulars" which he published—twelve in all—began as pamphlets of a couple of sheets, and ended as volumes of hundreds of

pages each, in which were brought together all the available material contributed to the common stock by the co-operating Observatories. Loewy's ideal was to provide for the man who should undertake the final discussion a mass of completely homogeneous material. The ideal was not completely attained; but the non-homogeneity which was found on discussion has served to indicate several unsuspected weaknesses in the Astrographic Chart and Catalogue.

Loewy's scheme provided from the first for a determination of the places of many stars along the track of the planet which had been, or might have been, used as comparison stars in the micrometric observations. The places of these stars, derived principally by the French Observatories, and by Helsingfors, Catania, and San Fernando, form a substantial product of the work, which should be of permanent value.

The heavy task of computing the eight-figure ephemeris of the planet was assigned by Loewy to Bossert, the chief of the *Bureau des Calculs* of the Paris Observatory. His ephemeris, from elements by Millosevich, formed the basis of the Greenwich reduction, and of the earlier reduction by Hinks. Neither Loewy nor Bossert lived to see the completion of the work to which they had contributed so much. But their successors, M. Baillaud as Director of the Observatory, and M. Lagarde at the *Bureau des Calculs*, undertook at a critical moment to calculate, with further refinements, completely new ephemerides based on new elements by Witt. On these ephemerides are founded the final solutions for the parallax and the mass of the Moon from the observations of 1900–01.

Perrine's detailed discussion of the Lick observations has recently been published (*Publications of the Carnegie Institution of Washington*, No. 119). His final value for the solar parallax is $8''{\cdot}8067 \pm 0''{\cdot}0025$. This result is affected by systematic differences, not yet fully explained, which lead to different conclusions according as the result is obtained from the separate observation equations or from the separate dates, and there is an element of arbitrariness in the assigned probable error. At the same time Perrine's work forms one of the most important of the contributions from individual observatories; it is to be hoped that when the photometric observations are available, his interesting study of possible connections between the light variations and periodic errors in the ephemeris may be completed.

Preparations for a further discussion of the solar parallax from a consideration of the various inequalities in the orbit of Eros has been undertaken, with the approval of the Paris Astrographic Congress, by Professor Strömgren.

The problem of determining the solar parallax has recently been tackled by spectroscopic methods. Professor Küstner's pioneer work in this direction (*A.N.*, vol. clxix. p. 241) was referred to in the President's address last year. Other radial velocity work has appeared from which values of the solar parallax could be deduced, but the one detailed investigation, so far published, dealing directly

with the question, is Messrs. Hough and Halm's spectroscopic determination of the constant of aberration and the solar parallax (*Cape Annals*, vol. x. part 3). Their value is

$$\pi = 8''{\cdot}800 \pm 0''{\cdot}006.$$

Mr. H. C. Plummer has pointed out (*Observatory*, June 1908) that this method gives directly a value of the constant of aberration, and that the derived value of the solar parallax suffers from any uncertainty in the velocity of light or the equatorial radius of the Earth. Hough and Halm have therefore also given their value for the constant of aberration, $20''{\cdot}473 \pm 0''{\cdot}015$. F. J. M. S.

Solar Activity in 1910.

Sun-spots.—As reported last year, the mean daily numbers and areas of sun-spots showed very little change in 1909 from those recorded in 1908. But with the opening of 1910 a great change became obvious, and the decline in the solar activity has now become very marked, the mean daily spotted area for 1910 being considerably less than half that for 1909.

The general form of the sun-spot curve in 1910 was as follows: The secondary maximum of September and October 1909 was followed by a steady and gradual decline until the end of the year. The decline became more rapid in 1910 January, but two remarkable disturbances caused a short revival in February. After these had passed out of sight at the west limb the decline continued until April, when a very marked secondary minimum occurred. A slight revival was observed in May, and the four following months were much on the same level, each showing only a few small groups of no great interest. But at the end of September a group which had been seen in two previous apparitions developed into a very fine irregular stream, group 6894, which at the beginning of October was quite the most remarkable disturbance of the year. After its disappearance the solar activity again declined, and no fresh outburst of importance was observed up to the close of the year.

The most important disturbances of the year were thus in February and at the end of September. Group 6813 (February 11–22) was a fine stream, inclined at a considerable angle to the equator, and consisting chiefly of two large spots, nearly circular in outline, connected by some small fainter formations on the south of the rear spot. The other disturbance in February was more complex, and extended over a wide area, being fully 20° of solar longitude in total length. It appeared at first as a number of loosely-formed, irregular little streams, in close proximity to each other. These became more compact as the disturbance approached the west limb, and it finally appeared as a great wedge, with a well-defined spot leading it.

The great disturbance, group 6894, seen September 27 to October 8, was a return of a fine "regular" spot that had been observed from August 4 to 15, and again from August 31 to September 11. But at its third appearance it had greatly increased in size and was now an immense composite spot, with many small companions, and followed by a train that was almost at right angles to the solar equator. Immediately preceding it was a straight stream, group 6893; and on October 1 and 2 the two groups together made up an almost continuous stream, nearly 20° in length, and visible to the naked eye. After passing the central meridian this fine stream began to break up, and by October 4 the chief spot was left almost alone.

A striking indication of the decline in sun-spot activity in 1910 has been the increase in the number of days upon which the Sun has been free from spots. Spots were seen on every day in only two months, January and March, and it appears probable that, when the photographic record is complete, more than fifty days in the year will prove to have been spotless.

As in the preceding years, the faculæ have shown fewer and less marked fluctuations than the spots. They have declined in numbers and area steadily throughout the year, but the falling-off as compared with 1909, or even with 1908, has been less than in the case of the spots.

The mean latitude for spots in the southern hemisphere was about 10°, in the northern hemisphere about 8°. No spots were seen in the northern hemisphere during the month of August 1910.

E. W. M.

Prominences.—The daily frequency of prominences during the year 1910 as deduced from 45 spectroheliograms taken on various dates between March 2 and October 10, is as follows:—

N.	2·6
S.	2·5
Total .	5·1

The photographs used were taken in "K_{2-3}" (calcium) light by means of the spectroheliograph of the Solar Physics Observatory, South Kensington. The minimum height of prominences taken into account was about 20″.

The above numbers indicate a small reduction in total activity since last year, the distribution remaining fairly equal in the two hemispheres.

Owing to the small number of photographs available, no attempt has been made to apportion the activity to latitude zones. Activity at the poles, however, was practically non-existent, though, on the other hand, large equatorial prominences were frequent.

In order to form a comparative, though only an approximate, view of the state of prominence activity in 1910, data for previous

years, deduced exclusively from South Kensington photographs, are given below:—

	1905.	1906.	1907.	1908.	1909.	1910.
N. . . .	3·4	3·9	3·5	2·5	2·9	2·6
S. . . .	3·0	2·6	3·9	3·1	2·7	2·5
Total .	6·4	6·5	7·4	5·6	5·6	5·1

The sequence of figures seems to indicate that the activity is now on its cyclic wane. The most recent values available of the mean daily frequencies, as deduced at the Kodaikánal Observatory from full data, both visual and photographic, show that the activity had not taken the downward path in 1909, the fall shown in 1908 being more than fully retrieved the following year.

The figures are as follows:—

	1905.	1906.	1907.	1908.	1909.	1910.
N. . . .	7·8	8·6	8·9	8·9	10·1	?
S. . . .	7·8	8·2	10·7	10·0	10·2	?
Total .	15·6	16·8	19·6	18·9	20·4	?

Certain prominence returns regularly communicated to the *Indian Monthly Weather Review* by the Kodaikánal Observatory indicate for the months January to August 1910 a slight decrease of activity from the mean of 1909.

It is therefore probable that the decline in 1910 as shown at South Kensington is real, and that prominence activity is now definitely, if somewhat slowly, on the downgrade. W. J. S. L.

Solar Research in 1910.

Sun-spot Spectra.—In continuation of his previous work on the apparent radial outflow of vapours from the interior of spots, Mr. Evershed has found evidence of a superposed rotatory motion, so that the vapours may be considered to travel outwards along spiral paths (*M.N.*, lxx. 217). The direction of rotation is anticlockwise in the northern hemisphere, and clockwise in the southern, in the case of the spots hitherto dealt with. Further investigation has also revealed a descent of vapours from above the spot with a velocity of about 0·4 km. per sec., and this is perhaps the source of supply for the outward radial motions. The upper strata of calcium vapour represented by the central dark lines H_3 and K_3 produce line displacements which indicate an *indraught* of these vapours towards the spot centres. The spiral motions of the lower vapours were reversed in direction as compared with the Hα vortices discovered by Hale, but the apparent discordance disappears, on the supposition that hydrogen partakes of the inward movement of the high-level calcium vapour. Mr. Evershed is inclined to

support the view that the rotational movements in the spots are secondary effects, the real electric vortex which produces the magnetic field in spots possibly being entirely beneath the reversing layer.

A further comparison of the sun-spot spectrum with the spectra of stars which lie near to the Sun in the presumed sequence of development, has been made by F. E. Baxandall (*Solar Physics Obs. Pub.*, 1910). The discussion deals with the region 3989 to 4353, and amply confirms Adams' conclusion that the lines strengthened in Arcturus, as compared with the Sun, are also strengthened in spots. It is suggested that the temperature conditions of the absorbing vapours in spot-nuclei are about the same as the mean temperature conditions of the absorbing vapours in Arcturus.

An important series of observations on the magnetic separation of absorption lines of sodium in relation to sun-spot spectra has been made by Zeeman and Winawer (*Ap. J.*, xxxii. 329). Striking reproductions of some of the modified appearances of lines in spots have been obtained with the aid of non-uniform fields.

Displacements of Lines at the Sun's Limb.—A further important contribution to the study of the displacements of lines at the Sun's limb, first discovered by Halm in 1907, has been made by Adams at Mt. Wilson (*Ap. J.*, xxxi. 30). These displacements are independent of the motion of rotation, and have been attributed to the somewhat greater effective pressure in the absorbing vapours at the limb than at the centre of the disc, a relatively greater thickness of vapour being traversed through the lower than the upper strata. Half the sum of the observed displacements at the west and east limbs gives the displacement due to rotation, and half the difference gives that attributed to pressure. Of the numerous results to which reference is made by Adams, it is only possible to mention a few. It occasionally happened that a plate which gave a correct value for the rotational velocity would give considerably more than average pressure displacements, and it is suggested that in such cases there was a general displacement of the lines at the centre of the disc towards the violet, brought about by radial convection currents, thus producing the apparent excessive displacements towards the red at the limb: the velocity of such currents is from 0·12 km. to as much as 0·23 km. per second. Lines of elements of very high atomic weight, such as lanthanum and cerium, show very small displacements; and it is suggested in explanation that most of the vapours of these elements lie so low that near the edge of the Sun they are eclipsed by the higher portions of the photospheric clouds, and the thickness traversed at the limb may then be no greater than that at the centre. Enhanced lines, as a class, show decidedly larger shifts than the arc lines; it may be that, as supposed by Evershed, the enhanced lines are produced by ascending highly-heated vapours, in which case the comparison lines obtained at the centre of the disc would themselves be displaced to the violet, and so produce an apparently increased shift to the

red, as compared with the arc lines due to stationary or descending cooler vapours. Direct comparisons of the limb and centre with the electric arc have shown that the displacements cannot be due to currents in the reversing layer parallel to the Sun's surface, and Mr. Adams fails to find any positive evidence in favour of the view that the effects may be due to anomalous dispersion. The whole question is greatly complicated by the differences of level at which the various lines originate, but all the present evidence seems to Mr. Adams to indicate that the observed shifts are due to pressure.

M. Perot has also critically examined the displacements at the limb, in order to determine whether they could be explained as an effect of displacements towards the violet at the centre of the disc, due to ascending currents (*Comptes Rendus*, cli. 38). It is concluded that the shifts cannot be explained in this way, and pressure or density is considered to be the most probable cause.

Dr. Julius, however, does not accept the explanation based upon pressure, but maintains that anomalous refraction and scattering provide a sufficient explanation of the observations (*Ap. J.*, xxxi. 426).

The Sun's Rotation.—An interesting investigation of the Sun's rotation periods, as determined from faculæ shown on photographs taken during 1906–08, at intervals of about 24 hours, has been made by Chevalier (*Ap. J.*, xxxii. 388). The number of plates utilised was 572, giving 2608 determinations of the period between latitudes 30° north and 30° south. The equatorial acceleration is clearly indicated, and it is concluded that the rotation of the faculæ in different latitudes does not differ more from the rotation of spots than the spots differ among themselves. The mean rotation, during the years of observation, appears to have been a little more rapid in the southern hemisphere than in the northern.

The Spectroheliograph.—As a contribution to the observation of solar and terrestrial phenomena about the time of transit of Halley's Comet, Mr. Slocum has reproduced direct and spectroheliograph pictures of the Sun taken on May 18 and 19, 1910 (*Ap. J.*, xxxii. 24). A group of spots near the centre of the disc displayed considerable activity, but there were no prominences of unusual size or intensity.

In another paper (*Ap. J.*, xxxii. 125), Mr Slocum gives series of photographs of two prominences of special interest; one on March 25, which had a brief but active existence; the other, from March 4 to April 28, which was remarkable for its great size, slow changes, and long life. The greatest height attained by the former was 319,500 km., at which altitude it floated as a detached cloud. The dissolution of eruptive prominences by vanishing upward in this way, rather than by subsidence, seems to be a characteristic of this type of prominence.

An important investigation which has some bearing on the

interpretation of calcium spectroheliograms has been carried on by Dr. St. John at Mt. Wilson (*Ap. J.*, xxxii. 36). It is found that the vapours which produce the absorption line K_3 have a descending velocity of 1·14 km. per sec., while those producing the adjacent K_2 lines indicate an ascending velocity of 1·97 km. per sec. No appreciable currents parallel to the Sun's surface were found. A possible cause for the high radiating power of the emitting (K_2) layer is increase of temperature, resulting from the transformation into heat of the mechanical energy set free by the loss of velocity in the opposing upward and downward currents. The average appreciable height of the chromospheric calcium is about 5000 km. above the photosphere, the upper absorbing layer having a thickness of about 1500 km.: allowing 700 km. for the reversing layer, the approximate thickness of the emitting layer would thus be about 3000 km.

An account of the work with the spectroheliograph carried on by M. Deslandres and his assistants forms vol. iv. of the *Publications of the Meudon Observatory* (1910). The new instruments are described in detail, together with the results obtained relating to the upper layers of the chromosphere, and the simultaneous study of the forms and movements of vapours. Many fine photographs are reproduced.

Solar and Terrestrial Phenomena.—Further references to the great magnetic storm of September 25, 1909, and its possible relation to outbursts in a sun-spot, have been made by Slocum (*Ap. J.*, xxxi. 26), Deslandres (*Comptes Rendus*, cl. 65), and Evershed (*Kodai. Obs. Bull.*, xxii.). Mr. Evershed's photographs of the red end of the spectrum of the spot on September 23, 24, 25 indicated a magnetic field of less than average intensity, but evidence is produced which tends to show that when there is a great outburst of gases the intensity of the field may be largely increased, so that the most active phase may easily have been missed. On September 28, in the same spot, there was evidence of a field approaching 10,000 units, or three and a half times the average, and this was accompanied by the second magnetic disturbance, already described by Professor Michie Smith (*M.N.*, lxx. 23). The observations suggest a possible connection between solar eruptions and simultaneous magnetic effects, not only on the Earth but also in the Sun itself.

The general question of the relation between sun-spots and magnetic storms is discussed at some length by Dr. Chree in *Nature*, vol. lxxxiii. p. 354

Dr. W. J. Humphreys has been led to conclude that the production of ozone by the action of the Sun's ultra-violet rays on the atmosphere may play an important part in controlling the variations of terrestrial temperatures (*Ap. J.*, xxxii. 97). An increase of spotted area on the Sun appears to be accompanied by a much larger decrease of temperature than can be accounted for by the decrease in radiation from the spot areas alone. At spot

maxima, the solar atmosphere perhaps contains increased amounts of dust, so that the ultra-violet radiation of the Sun would then be diminished; the amount of ozone in the upper atmosphere would be lessened; and as this gas absorbs the radiations from the Earth more strongly than the direct rays from the Sun, the diathermancy of the air would be increased, and a cooling of the Earth and of the lower atmosphere would result. The effect, however, tends to be compensated by the production of ozone by auroral discharges, which are most frequent at spot maxima, and further investigations are suggested.

Miscellaneous.—Dr. Kempf has found several cases of distinct rotatory movements of spots about their own centres among the Potsdam records for 1891–93. The direction of rotation was mostly anticlockwise, but opposite rotations occurred in the same hemisphere (*Ast. Nach.*, 4429).

Mr. A. A. Buss has given an interesting account of his observations and study of solar phenomena during the last fifteen years (*Observatory*, xxxiii. 359, 399, 432), which should be a great encouragement to observers who are only provided with small instruments. Among other points of interest, Mr. Buss is convinced that he has on several occasions witnessed beginnings of spot-formation in latitudes far outside those usually assigned to spots, and he also believes that masses of absorbing vapours, at great heights above the Sun's limb, are sometimes visible by projection against a feebly luminous atmosphere of the Sun. A. F.

The International Union for Co-operation in Solar Research.

The Fourth Conference of the International Union for Solar Research was held at the Mount Wilson Solar Observatory, California, on the invitation of Professor Hale, from August 31 to September 2, 1910. Notwithstanding the long journeys demanded of most of those who desired to attend, the opportunity of visiting the Solar Observatory under such favourable circumstances attracted a larger gathering than any previous meeting of the Union. Of the 83 astronomers and physicists who attended the Conference, 46 were from the United States, 9 from France, 9 from Germany, 8 from Great Britain, 3 from Russia, 2 from Canada, and 1 each from Austria, Holland, Italy, Spain, Sweden, and Switzerland. Messrs Cortie, Dyson, Fowler, Hills, Larmor, Newall, Schuster, and Turner were the British delegates.

The arrangements made by Professor Hale and his staff for the convenience and comfort of the visitors, as well as for the actual business of the Conference, were in every way admirable. The date of the Conference was thoughtfully chosen so as to permit those who desired to do so to accept the invitation of the Astronomical Society of America to attend the annual meeting of

that Society at the Harvard College Observatory, and afterwards to make the journey across the continent together in the special cars which had been reserved. Including the time occupied by the Conference, many of the delegates were in this way brought together for three or four weeks, and the unique opportunity of making acquaintances and of discussing matters of mutual interest was greatly appreciated.

On the outward journey, among other places of interest the party visited the University of Chicago and the Lowell Observatory, and arrived at Pasadena on August 28. The laboratory, workshops, and computing offices were open for inspection on August 29, and, among the many features of interest, the gigantic slit and camera fittings for the new spectroheliograph of 75 feet focal length, and the machine for grinding the 100-inch mirror, attracted special attention. The greater part of the following day was occupied by the ascent of Mount Wilson, and by a preliminary examination of the remarkable instruments which have been erected on the summit.

The first formal meeting of the Conference was held on August 31, with Professor E. C. Pickering as chairman. Professor Hale opened the proceedings with a characteristic address, in the course of which he welcomed the members of the Union, and expressed the opinion that the Conferences did more to stimulate research, through the opportunities for personal intercourse and discussion which they afforded, than by the organisation of formal co-operation in the work of observation. The new Tower Telescope, of 150 feet focal length, with its double framework for the elimination of vibrations set up by winds, was described in some detail, and an account was given of the latest results in connection with the magnetic fields in sun-spots. To the great regret of everyone present, Professor Hale was unable to take any further part in the meetings in consequence of illness brought on by overwork, but, thanks to his admirable foresight, the subsequent proceedings were carried on very smoothly.

The work of the Union is chiefly conducted by numerous committees, and the greater part of the business of the meetings was to receive and discuss the reports and recommendations presented by them. Through Professor Kayser, the Committee on standard wave-lengths recommended the adoption, as secondary standards, of the mean values of the wave-lengths of forty-nine iron lines, for which three sufficiently accordant and independent interferometer determinations had been made by Fabry and Buisson, Eversheim, and Pfund. At the present time such measures are confined to the region 4282–6494 (see *Ap. J.*, xxxii. 215), but the results of other determinations outside this region will be similarly adopted without waiting for formal approval by the Union. In the region about λ5800, where iron lines are rather sparse, certain lines of barium are proposed as additional standards. Laboratories and observatories possessing sufficiently powerful spectrographs are invited to determine as soon as possible, by the

ordinary methods of interpolation, the wave-lengths of the remaining lines of iron, to serve as standards of the third order, and also to make measurements of arc, spark, and solar spectra on this new international scale. The recommendations of the Committee were unanimously agreed to, and it may be expected that the new scale will now be generally employed for all spectroscopic work of high precision, and eventually for all spectroscopic measurements. On the average, the new wave-lengths are about 0·19 Ångström units lower than Rowland's values, but the deviation varies from 0·15 to 0·22 in different parts of the spectrum. It may be added that many tertiary standards of iron have already been determined by Professor Kayser, and that the table which he has lately published (*Ap. J.*, xxxii. 217) comprises all the standards which are at present available.

The meeting on September 1 was presided over by Professor Campbell, and reports were presented by the Committee on Solar Radiation, Sun-spot Spectra, and Eclipses. On behalf of the Solar Radiation Committee, Mr. Abbot gave a valuable account of the present state of our knowledge on this subject, and indicated the nature of the observations and experiments which are necessary for further advances. The recent work of the Smithsonian observers at Washington and Mount Wilson has yielded numerous independent and concordant determinations of the "solar constant of radiation," all of the order of 2·0 calories per square centimetre per minute, and has also indicated, with a fair degree of certainty, that there are frequent variations of the order of 5 to 10 per cent. in the intensity of solar radiation outside the Earth's atmosphere.

Langley's method of determining the solar constant by spectrobolometric observations of homogeneous rays at high and low Sun, with simultaneous pyrheliometric observations (*Ann. Astrophys. Obs. Smithsonian Inst.*, vol. ii., part i.), is considered competent to give substantially accurate results on any good day, independently of the altitude of the place of observation, the relative values at Mount Wilson having a probable error of less than 0·5 per cent. Simultaneous observations at another station at least as good as Mount Wilson, however, are regarded as urgently necessary. The empirical methods of Fowle and Ångström are also promising, and it is recommended that several mountain stations in different parts of the world should undertake daily pyrheliometric determinations, with a view to throwing further light on the question of solar variability. It is also hoped that further experiments may be undertaken in several physical laboratories, with a view to establishing a much-needed standard scale of pyrheliometry. The state of knowledge as to the amount, distribution, and spectral quality of the solar radiation, diffusively reflected by the atmosphere, is considered to be quite unsatisfactory, and the subject is recommended as offering a promising field of research. Records of the distribution of intensity of radiation over the Sun's disc should also be resumed, as they will probably be of value in relation to the supposed variability of the Sun.

The report on the spectra of sun-spots was presented by Mr. Fowler. Six observers had undertaken to co-operate in making systematic observations on the plan proposed by the Committee, in order to obtain data for the discussion of the general phenomena, and to determine the nature of the changes, if any, with variation in the spot period. The first object in view has been completely realised by photographs which have been obtained since these observations were commenced, and further efforts to map the entire details of the spot spectrum from visual observations are regarded as superfluous. The Committee considers, however, that visual observations should be continued, and proposes to prepare a list of representative lines, the observation of which will probably suffice to reveal any considerable variation from spot to spot. Visual observations of the hydrogen and helium lines in the vicinity of spots have in no way been superseded by photographs, and it is hoped that observers having only moderate instruments will continue to record these phenomena. Observers are also recommended to give careful attention to the behaviour of lines in the penumbra and circumpenumbral regions as compared with their appearances in the umbra, and also to investigate the spectrum of the Sun's disc just within the limb in relation to the spot spectrum. The most striking result of the observations reported upon by the co-operating observers is the remarkable constancy of the spectra of spots during the period of observation 1904–1909, except as regards the hydrogen and helium lines. The observations, however, were made with comparatively small instruments, and would therefore probably take no account of possible changes during the growth and decline of spots, and most of the observations were made about the time of maximum spot period. With regard to photographic work, the Committee recommended that those engaged in the preparation of catalogues of affected lines should co-operate by the intercomparison of their manuscript catalogues, and if possible by the final collection of all their results into a single catalogue.

The meeting on Friday, September 2, was presided over by Professor Frost. Mr. Adams presented the report of the Committee on the determination of the Sun's rotation by the displacements of lines, from which it appeared that active co-operation in this important work was to be immediately established. Six observers have agreed to give special attention to as many different regions of the spectrum, and, in addition, to investigate a region common to all, so as to provide a check on the general accuracy of the work.

The report of the Committee on the spectroheliograph indicated the work which had been accomplished by the co-operating observatories, and recommended the continuation of daily photographs of calcium flocculi. It was considered desirable that provision should be made for the measurement of the photographs, and the Committee recognises the growing importance of spectroheliographs of high dispersion. The Observatories of Tacubaya and Madrid

have been added to the list of co-operating institutions for this work.

The final meeting was set apart for a discussion as to whether the scope of the Union should be extended so as to include general astrophysics in the range of its activity. It was generally recognised that investigations of the stars are a necessary complement to those of the Sun, and it was unanimously agreed that the proposed alteration in the constitution of the Union should be made. The immediate outcome of this decision was the appointment of a Committee to consider and report on the classification of stellar spectra.

During the Conference, the members of the Union were granted every facility for seeing the various instruments at work, and also for making individual observations. Magnificent views of nebulæ and star clusters, and of the planet Saturn, were obtained with the 60-inch reflector, through the kindness of Mr. Ritchey.

After the Conference, many of the members took advantage of invitations to visit the Lick, Berkeley, Yerkes, and other Observatories.

The next Conference will be held at Bonn in 1913. A. F.

Double Stars.

The abbreviations used are —

M.N. : *Monthly Notices.*
A.N. : *Astronomische Nachrichten.*
L.O.B. : *Lick Observatory Bulletin.*
B.A.A. : *Journal of the British Astronomical Association.*

New Doubles and Measures of known Pairs.—The Rev. T. E. Espin continues his survey of the zone $+44^{\circ}$ to $+55^{\circ}$ dec., and contributed 120 new double stars to the *M.N.*, 1910 January, and a further 63 in *M.N.*, May. Mr. Espin employs a $17\frac{1}{4}$-inch reflector, and in general the companion discovered is faint. 37 of the above pairs are under $3''$ separation, and 49 are between $3''$ and $5''$.

Dr. R. G. Aitken, continuing his systematic search for new doubles with the 36-inch Lick refractor, has brought his total discoveries up to 2200 by the addition of 100 new pairs in *L.O.B.*, 184. Of these 100 pairs, 28 are under $0''{\cdot}5$ separation.

Mr. E. D. Roe, Syracuse, U.S.A., $6\frac{1}{2}$-inch Clark, has brought his total discoveries up to 35. These will be found in *A.N.*, 4381 ; *Popular Astronomy*, 176 ; and *Astronomical Journal*, 611.
He also contributes measures of 39 pairs in *A.N.*, 4381.

Mr. Innes, at Johannesburg, having the 9-inch Grubb refractor, but not the micrometer which was ordered in 1908, has made careful estimates of the angles and distances of 268 new doubles,

115 of which are under 1″ separation. This makes Mr. Innes's total discoveries 700. He also gives estimates of 50 known pairs. These are published in Circular No. 1 of the *Transvaal Observatory*. The altitude of the instrument is 5900 feet.

M. Robert Jonckheere, who has built an observatory at Hem, Nord, France, is devoting a great portion of his time to double-star work. He employs a 13·8-inch refractor whose focal length is 21·3 feet. M. Jonckheere measures known pairs and searches for new ones, and his results are published in journals issued from the observatory. There are at present 13 numbers of the *Journal Astronomique*, the first dating 1909 September 15. These contain 300 new doubles, of which 101 are separated less than 2″, and only 20 exceed 5″; and measures of 282 known pairs made in 1909 and 1910. Of these, 70 are less than 1″ separation.

B.A.A. Journ., vol. xxi., No. 1, contains measures of 6 southern pairs by Mr. J. Nangle with the 6¼-in. Clark refractor at Stanmore, New South Wales.

Mr. G. D. Hirst (4¼-inch Cooke, Sydney) contributes to *M.N.*, March and June, measures of 39 southern pairs made in the years 1906–7–8–9.

There are a few measures made by Mr. Tebbutt in *M.N.*, Supp. No., p. 655. These include γ Cor. Aust., β 416, α Centauri. Other measures of southern stars will be found in *A.N.*, 4166, 4227, 4360. This series, made by Messrs. Olivier, Neff, and Wilson, has been added to by Mr. Olivier, who has measured 136 pairs, mostly with the 12-inch refractor at Lick, a few being measured with the 36-inch. This very useful series is in *L.O.B.*, 175.

Messrs. Lau and Callisen publish in *A.N.*, 4436, measures of 134 Struve wide pairs. A miscellaneous set of 61 stars in the region +60° to 90° N. dec., will be found in *A.N.*, 4425. These are by Herr Jost with the 6-inch Strasburg refractor, and range from 1″·1 to 182″·5 separation.

In *A.N.*, 4426, Professor Burnham publishes measures of 214 pairs made with the 40-inch Yerkes refractor. These are wide pairs, and form a portion of Professor Burnham's systematic measures for proper motions.

Dr. Doberck has now been settled at Sutton for two years. During this period he has measured over 600 pairs. His last series of 327 pairs is in *A.N.*, 4394–5; of these, 134 are under 2″ separation.

In the *Astronomical Journal*, No. 611, Mr. Philip Fox gives measures of 171 pairs made with the 12- and 40-inch refractors at Yerkes, and the 18½-inch refractor of the Dearborn Observatory, of which Mr. Fox has become the Director in succession to Professor Hough.

In *M.N.*, 1910 January, is the Rev. T. E. Espin's seventh series of measures made with the 17¼-inch reflector at Tow Law, Co. Durham. These consist for the most part of Herschel pairs, ranging from 4″ to 24″ separation, and of 56 miscellaneous pairs, of which 20 are under 5″ separation.

The usual annual list of mean results of measures made with the 28-inch Grubb refractor at Greenwich is in *M.N.*, June. In all, 576 pairs were measured, but only those whose separation is under 4″ are given. Of these 464 pairs, 215 are under 1″ separation.

Misure di 636 *Stelle doppie e triple* contains the measures made by Professor G. Schiaparelli with the 19·2-inch refractor at Milan during the period 1886–1900. The stars measured are those of the W. Struve, O. Struve, Burnham, and Hough catalogues, the measures being in continuation of those of 465 stars made during the period 1875 to 1885 with the 8½-inch refractor, and published in 1888. Thus the two volumes complete a quarter of a century's work in this one branch of Astronomy. These two volumes contain 10,958 measures of 1101 stars, in which are included κ Pegasi, δ Equulei, 85 Pegasi, and ϵ Hydræ (Schiaparelli), and splendid series of 70 Ophiuchi, ζ Boötis, ξ Boötis, η Coronæ, γ Coronæ, ζ Herculis, 42 Comæ, ξ Ursæ Majoris, ζ Cancri, etc. This volume also contains a complete description of the 19·2-inch refractor and its fittings.

Computational and Theoretical Papers.—Dr. Doberck publishes in *A.N.*, 4383, an orbit of Σ 1768, 25 Can. Ven., period 553 years.

Miss F. Brown has a note on the orbits of ϵ Hydræ and β 883 in *Ast. Soc. Pacific*, 129.

B.A.A. Journ., vol. xxi., No. 1. Mr J. Nangle, President of the N.S.W. Branch of the *B.A.A.*, gives measures and a provisional orbit of *h* 5014, period 141 years.

In *Observatory*, No. 422, is an "analytical method of finding the orbit of a double star" by H. C. Plummer, who, starting with the general equation to the ellipse, deduces a similar (but independent) set of relations to those found by Kowalski.

In *Observatory*, No. 419, Mr. Innes, in a note on double-star magnitudes and identifications, points out the importance of uniformity in determining magnitudes, and the great trouble it would save if double stars discovered were carefully identified in the ordinary meridian catalogues.

In No. 421 Mr. Aitken bears out the statement of Mr. Innes that double-star observers have a tendency to overestimate the brightness of stars discovered, and finds that to bring the magnitudes into line with those of the B.D. a correction of +0·2 mag. should be applied to those of W. Struve and Aitken, +0·3 to Hussey, and 0·4 to Otto Struve.

In *Bulletin Astronomique*, 1910 April, M. Lau rediscusses the results for magnitudes of double stars obtained by Herr Thiele with the large refractor of the Copenhagen Observatory (*A.N.*, 4224). From a comparison with Harvard magnitudes he concludes that a coefficient of the formula connecting exposure and magnitude deduced by Herr Thiele is seriously inexact—0·55 should replace 0·35—and that in consequence the Copenhagen magnitudes must be revised before they are used in researches on the evolution of double stars.

Dr. Aitken, in *L.O.B.*, 136, has a note on "the relation between separation and number of visual double stars," in which he shows that of double stars catalogued—

1. The actual number of close pairs exceeds that of moderate separation.

2. That increase in number progresses with decrease in separation.

Dr. Comstock, taking the list of stars given by Otto Struve in the *Pulkovo Publications* as showing proper motion, has re-measured them, and collected all other measures he could find. The results of these measures are then discussed in connection with the known proper motion of the principal star, and proper motions for the fainter companion found. There are in all 226 such pairs, ranging from 5″ to 400″ separation, and the measures, including those of Dr. Comstock (1902–1907), with the discussion, are published as vol. xii. of the *Washburn Observatory Publications*. It should be most useful for investigators in this branch.

The separate study of a particular case of stellar evolution, viz. the relative development of binary stars, has much advanced recently, by reason of the large number of known spectroscopic binaries. Messrs. Schlesinger and Baker give a very clear exposition of our present knowledge, in the *Allegheny Publications*, vol. i., No. 21, and in *Observatory*, No. 426.

The same subject is dealt with by Professor Campbell in *L.O.B.*, 181, under the title "Second Catalogue of Spectroscopic Binaries."

In the *Astrophysical Journal*, 1910 April, Henry Norris Russell discusses the same problem from another point of view, and arrives at the conclusion that "it is apparently necessary to assume that star clusters have developed from originally separate nuclei, and more reasonable to suppose that binary stars have originated by fission." In the same number is an article "on star colours," by Professor Louis Bell, who, from experiments with artificial stars, arrives at the conclusion that subjective colours play the chief, if not the only, *rôle* in determining apparent tints, and that there is very little initial difference of colour.

Of other papers bearing on double stars we may mention the "Letters of the Rev. W. R. Dawes," published in *Observatory*, Nos. 426, 427, 428, and the series of articles by Mr. Chambers in *Knowledge*. T. L.

Variable Stars.

The year 1910 is characterised by steady work and progress in this branch of Astronomy.

The total number of new variables registered by the Committee of the *A.G.* was for 1909, 46; for 1910, 131.

A.N., 4457, gives a list of 126 newly established variables, with the lettering and full particulars.

Among the regular observers and workers appear the names of

Astbury, Ceraski, De Roy, Enebo, Ichinoe, Münch, Nijland, Pračka, Van der Bilt, Whiteside, Yendell, and others, including the variable star section of the B.A.A. It is only possible here to refer to a selection from some of the more prominent items of work done.

Four of the Harvard College Circulars announce the following discoveries, which are included in the register of the *A.G.*

No. 152.—20 new variables in Harvard maps 2, 5, 32, 44, and 53. All these are telescopic variables, the brightest at max. rising to 7·9 m., the faintest at max. to 10·6 m.

No. 158.—38 new variables. The brightest at max. reaches 6·0 m., the faintest 11·1 m. These were discovered by Mrs. Fleming in examining the spectrograms of the Henry Draper memorial.

No. 159.—15 new variables in Harvard maps 7, 10, 16, and 19, discovered by Miss Cannon. All these are in the northern hemisphere, the brightest at max. 7·8 m., the faintest 10·5 m.

No. 162.—22 new variables in Harvard map 52, discovered by Miss Cannon, all being in the S. hemisphere. Some of these have a range of 3 magnitudes; the brightest at max. 7·6 m., the faintest 10·5 m.

A. Stanley Williams has discovered a new Algol type variable (28, 1910 Cygni). The light-curve is flat at min. Elements—min. = J.D. 2415704·451 + 0^d·969186 E., max. 10·53 m., min. 11·39 m., range 0·56 m. (*A.N.*, 4398.)

T. H. Astbury announces a new variable (39, 1910 Cephei) = B.D. + 71° 1070 (9·5 m.), R.A. (1900) 21^h 28^m 19^s·88, Dec. + 71° 30′ 3″·4. (*A.N.*, 4410.)

Professor E. C. Pickering announces a new star in position R.A. 17^h 52^m 15^s, Dec. − 27° 32′·3 (1875), discovered by Mrs. Fleming on 1910 October 1. It appears on 16 photographs taken at Arequipa, magnitudes 7·8 to 8·6. It does not appear on 17 plates 1889 July 23–1909 October 7, although these show stars to 12 m. Is was observed visually at Harvard on 1910 October 3, in the 24-inch reflector, 10·5 m. (*A.N.*, 4448.)

A new star or a new variable (97, 1910) has been discovered by A. R. Hinks on three photographs taken at the Cambridge Observatory with the Sheepshanks equatorial on 1909 August 7, 10 and 12. Position, R.A. 19^h 49^m 55^s·01, Dec. + 36° 46′ 57″·4 (1900); magnitudes 10·4, 10·2, and 10·5. A visual search on 1910 September 19 and 26 showed no star so bright as 13 m. in the place. (*A.N.*, 4448.)

Nova 98, 1910 Arae, in R.A. 16^h 31^m 4^s, Dec. − 52° 10′·6 (1875) was discovered by Mrs. Fleming on 1910 October 13. This object appears on 21 photographs taken at Arequipa between the dates 1910 April 4 and 1910 August 3. Magnitudes 6·0 to 10·0. It apparently passed into the nebulous state before the spectrum was photographed. It does not appear on 44 plates taken between 1889 August 20 and 1910 March 19. (*A.N.*, 4450.)

Professor Pickering in *A.N.*, 4459, announces Nova 132, 1910 Sagittarii 3, discovered by Miss A. J. Cannon. Position, R.A.

$18^h\ 12{\cdot}2^m$, Dec. $-25°\ 14'$ (1875). A photograph taken on 1899 August 9 shows no trace. The outburst of the star must have been very sudden, as on the next evening, August 10, it was conspicuous, being 8·5 m. It faded from 8·6 m. on August 25 to 10·5 m. on 1889 October 13, after which the decrease was more gradual.

A.N., 4381, contains a paper on u Herculis by N. Ichinoe. This variable was discovered by Schmidt in 1869, and the light-curve up to now was thought to be irregular. It is now found to be of the β Lyræ type. This was first deduced from spectroscopic observations at the Allegheny Observatory, and Harvard photometric observations. In *A.J.*, 610, P. S. Yendell deals with the same star, and finds the variation distinctly of the β Lyræ type. Elements of principal min., 1888 July $11^d{\cdot}4812$ G.M.T. $+ 2^d{\cdot}05064$.

In *A.N.*, 4382, T. H. Astbury gives the elements of the Algol variable 16, 1908 Vulpeculæ, from nearly 300 observations by three observers. Min. = J.D. $2418287{\cdot}24 + 4{\cdot}4764$ E.

In *A.N.*, 4385, the light-curve of the short-period variable η Aquilæ is determined and drawn from photographs by A. Kohlschütter. The minor inflexions shown on this curve are very similar to those found in the curve from visual work.

A. Stanley Williams points out in *A.N.*, 4393, that in 1905 the variation of RX Andromedæ differed from the typical U Geminorum variation. He concludes also that SS Cygni, whose changes are similar to RX Andromedæ, had in 1908 temporarily changed from type of U Geminorum to an irregular variable. May there not, he asks, be some common physical cause affecting both the rapid or short-period irregular variables and those of the U Geminorum type; or may not the two types be merely varieties of the same common variation?

Sperra finds the light variations of both SU and SW Draconis to be of η Aquilæ type, with curious minor fluctuations. (*A.N.*, 4407.)

M. Luizet has determined the curve of SY Cassiopeiæ, which shows a very sharp peak (*i.e.* rapid change) at max.; it is of δ Cephei type; period $4^d{\cdot}06976$. (*A.N.*, 4434.)

In *A.J.*, 617, P. S. Yendell deals with R Lyræ (period formerly thought to be $46^d{\cdot}4$), and W Cygni (period up to now 131^d). He finds R Lyræ to have a period of $0^d{\cdot}97955$; Var^n. 4·4 m. to 5·1 m. W Cygni to have a period of $0^d{\cdot}9924$; Var^n. 5·52 m. to 6·49 m. The two light-curves are identical, and practically the same type as ζ Geminorum.

Professor E. E. Barnard gives the period and light-curve of the variable No. 33 M 5 (Libra), and suggests the use of such a star as a time constant. Might it not be possible to use a number of such stars as this as a check on the constancy of the Earth's rotation? The period $= 0^d{\cdot}5014734050$. (*A.N.*, 4409.)

In *A.N.*, 4423, W. S. Franks discusses the colours of 261 variables. The following results are obtained:—(Abbreviations,

II. = long-period class; III. = small range of variation; IV. = short period; and V. = Algol type).

Class.	Spectrum.	Colour.	Stars.	Percentage.
V.	A–B	White	14	5·4
IV.	G	Pale yellow	24	9·2
II.	Md	Or. yellow to Or. red	165	63·2
III.	N	Or. red	58	22·2

Herr L. Pračka has brought out a special work giving the observations of twenty-three well-known variables by Dr. Safarik of Prague. These stars are contained between 0^h and 5^h 6^m of R.A. As an example of the period covered by these, it may be mentioned that the observations of S Cassiopeiæ extend from 1880 February 7 to 1894 July 6, while those of *o* Ceti extend from 1871 August 25 to 1891 September 3. For each variable the comparison stars used, the observations of brightness, and the discussion of the light curve, etc., are given very completely, and the whole volume appears to be a careful piece of work.

An apparently new star was discovered by the Rev. T. E. Espin, in Lacerta, on 1910 December 30. The published particulars at time of writing are but few, and the character of the new star is not yet fully determined. The position of the object is given by the discoverer as R.A. 22^h 32^m $8^s·9$, Dec. $+52°$ $14'·6$ (1910). When first seen in the twilight it was estimated 8·0 m., but as it was red its real brightness was then probably a little under 7·0 m. It was estimated on 1911 January 3 as 7·7 m., January 6, 7·9 m., and January 10, 7·9 m.

From information received from H.C.O. it appears that the star was invisible (on the photographic plate) on 1910 November 19, while on November 23 and December 7 it was rated at 5·00 m. This would seem to indicate that the star is a Nova, as we are not aware of any regular long-period variable rising from invisibility to the fifth magnitude in four days. Further observations will be awaited with great interest. E. E. M.

The Photography of Nebulæ.

The publication of the late Professor Keeler's photographs of nebulæ and clusters made with the Crossley reflector,* and the more recent account of the completion of the 60-inch reflector by Professor Ritchey at Mount Wilson,† invite an examination of the results achieved in the period of about twenty-five years, during which the photography of nebulæ has been practicable.

If we exclude for the moment the diffused nebulosities of great extent photographed by Barnard and Max Wolf with portrait lenses, there remain the relatively small nebulæ, for which the silver-on-glass paraboloidal mirror is especially suitable; the annular

* *Publications of the Lick Observatory*, vol. viii., 1908.
† *Astrophysical Journal*, 1910 July.

and planetary, the network and the irregular nebulæ, whose spectra, as far as they are known, are gaseous; and the spirals, whose spectra are, in the few cases examined, continuous. The extreme importance in cosmogony of a detailed study of nebular structure, and of the distribution of the several kinds with respect to the galactic plane, makes it particularly desirable that we should possess systematic collections of photographs made under somewhat uniform instrumental conditions.

Of such collections we now have two: the photographs made by Isaac Roberts between 1885 and 1899, published in his two well-known volumes dated 1893 and 1899; and the photographs made with the Crossley Reflector in 1898 to 1900 by Keeler, whose programme, interrupted by his untimely death, was completed under the charge of Dr. Perrine.

The number of separate nebulæ figured in these two collections is nearly one hundred; and—always excepting the very extended nebulæ—the number photographed by other observers, but not found in the publications of Crowborough and Mount Hamilton, is quite inconsiderable. There are a small and interesting series of planetary nebulæ photographed at Stockholm by Professor Bohlin;* some valuable photographs of southern nebulæ by Mr. Knox Shaw at Helwân, recently presented to the Society, but as yet unpublished; and we should include, perhaps, a few of the smaller of the extended nebulæ by Professor Barnard and Dr. Max Wolf. The extraordinarily fine pictures obtained by Professor Ritchey at the Yerkes Observatory, and recently at Mount Wilson, are all of comparatively well-known objects.

The material at our disposal for a systematic study of nebulæ is almost confined, then, to the two collections mentioned above. If we analyse them we obtain the following figures:—

11 nebulæ are given by Roberts and Keeler, and also by Ritchey.
35 are given by both Roberts and Keeler.
1 by Roberts and Ritchey.
30 are given by Roberts only.
20 by Keeler only.

These figures are for the published photographs.

Included in the observed programme of the Crossley reflector are thirty-six objects not reproduced, "for the most part small, or apparently not of special interest." Of these, thirty-two are nebulæ, and an examination of the list shows that seven are given by Roberts, and twenty-five have never yet been published, though three of them (N.G.C., 1023, 6412, and 6656), may be found among the prints and transparencies presented to the Society by Isaac Roberts; and one (N.G.C., 5247) is among the slides recently received from Helwân.

An examination of the lists of photographs made year by year at Crowborough, as given in the annual reports of the observatory, and recently catalogued by Mrs. Isaac Roberts, shows that there

* "On the Galactic System," *K. Svenska Vetensk. Akad. Handlingar*, Bd. 43, No. 10.

remain unpublished a very large number of plates representing nebulæ of which we know practically nothing. In view of the fact that scarcely any progress was made in the systematic photography of nebulæ for several years in the beginning of the present century, it is much to be wished that some means may be found of publishing without delay the extremely valuable material obtained by Isaac Roberts and Keeler which does not appear in their published collections.

While the greater part of the nebulæ catalogued by William Herschel remain unphotographed, great numbers of small uncatalogued nebulæ have been found by photography in the fields surrounding well-known objects. The plates of the 104 objects in Keeler's programme contained the images of 744 nebulæ not previously observed. A catalogue of their positions, by Messrs. Palmer, Curtis, and Albrecht, is given in the Crossley Reflector volume. And finally, Professor Ritchey has obtained a photograph of the field surrounding Messier 97 (N.G.C., 3587), in which the new nebulæ are more numerous than the stars. Very extensive lists of new nebulæ have also, within the last few years, been given by Dr. Max Wolf (*Publicationen des Astrophys. Observatoriums Königstuhl-Heidelberg*, vols. i.–iii.), and by Professor E. C. Pickering, from plates taken with the Bruce telescope at Arequipa (*H.C.O. Annals*, vol. lx., No. 6). The same volume contains two useful memoirs by Professor Bailey: "A List of Bright Nebulæ," and "An Index of Published Photographs of Nebulæ."

While for the moment no one was found to continue the orderly surveys of Roberts and Keeler, immense progress has been made in instrument construction, and results have been obtained which in delicacy and refinement of detail greatly surpass the work of the older instruments. This progress is due in great part to the instrument shops of the Yerkes Observatory, and of the Solar Observatory at Pasadena, in which Professor Ritchey has made splendid use of the unequalled means at his command. His developments in the methods of figuring and testing paraboloidal and hyperboloidal mirrors are of the highest interest, but require great resources. The figuring of the paraboloid for the two-foot reflector involved, as an incidental, the figuring of a plane of equal diameter. In figuring the five-foot, however, Professor Ritchey has succeeded in making a three-foot plane do, instead of the full five-foot, but at some inconvenience.

The mounting of the five-foot embodies a great number of refined constructions, of which a preliminary account is given in *Astrophysical Journal*, 1910 July. The double, air-tight dome, and the non-conducting refrigerated canopy, which during the day maintains the instrument at the expected night temperature, are devices which add much to the cost of the instrument and the trouble of operating it. It will be interesting to see if, after long experience of them, they are retained as indispensable features of future construction. Perhaps the most remarkable of the many novel features of this magnificent instrument is the method of

focussing by the knife-edge test, familiar in optical testing, but not hitherto used in the hourly manipulation of an instrument. In long exposures the plate is removed every forty minutes, and the focus redetermined by this test. Inasmuch as the theoretical diameter of the smallest star disc is given as 0″·074, while the smallest realised diameter is 1″·03, it remains to be seen whether the knife-edge test is not over-sensitive; that is to say, whether defects of figure, due to temperature changes, may not be conspicuous in the test, without producing any sensible effect on the size of the smallest realised images. On this and on many other questions raised by the extreme refinements introduced into this instrument, all makers and users of reflecting telescopes will await with great interest the information drawn from further experience.

The Society is indebted to Professor Ritchey for a magnificent series of enlargements from negatives made during the last year. They are especially remarkable for the brilliant definition of fine nebular details, scarcely larger than the minimum star discs obtainable. Their author lays stress on the advantage he gains in using relatively slow plates, whose fineness of grain undoubtedly contributes much to the beauty of the enlargements. A device which has also played a considerable part in bringing out detail in the bright centres is the differential printing by means of paper screens, which has superseded the tedious but very successful local reduction of the negative employed by Professor Ritchey at the Yerkes Observatory.

With all possible mechanical aid provided, the strain of the continuous attention required in long exposures is so great that no man can work such an instrument continuously. It is much to be hoped that the resources of the Mount Wilson Solar Observatory will allow the provision of an ample staff devoted to the 60-inch reflector, and that it may be thus possible to undertake that systematic photography of the less brilliant nebulæ which, since the death of Keeler and of Isaac Roberts, has been pursued only in the last two years by Mr. Knox Shaw, working single-handed with the Reynolds reflector at Helwân.

The immense extended nebulæ in the Milky Way require treatment so different that it is more convenient to consider them apart. Far too large for the restricted field of the reflector, they must be dealt with by the portrait lens. The admirable specimens of the work of the Brashear 10-inch doublet at Mount Wilson in 1905, which Professor Barnard gave to the Society in 1906, are of the first importance in a study of the relations between the star clouds, the nebulæ, and the dark lanes which have the appearance of absorbing matter. The Carnegie Institution has announced the publication of an Atlas of the Milky Way by Professor Barnard; its appearance is awaited with high expectations. And the occasional fine plates published by Professor Max Wolf — see, for instance, the "America" nebula which forms the frontispiece of his first volume of publications, or the plate in *M.N.*, vol. lxiv. p. 838 — cause regret that no collection of photographs made with the Heidelberg Bruce Telescope is available for study. A. R. H.

Stellar Spectroscopy in 1910.

Nebulæ, Novæ, Wolf-Rayet Stars.—New lines have been photographed in the spectrum of the Orion nebula by W. H. Wright (*L.O.B.*, 183, vol. vi. 61). Four are identified as belonging to the hydrogen series; they correspond to the values 13, 14, 15, 16 in Balmer's series, where H_a corresponds to the value 3. Wright also finds in the spectrum of the nebula N.G.C. 7027, red lines, hitherto unrecorded, at wave-lengths 6301, 6548, 6583.

In the spectrum of the America nebula in Cygnus, Dr. Max Wolf (*Sitz. ber. Heidelberger Akad.*, 1910, No. 27) finds many bright lines, the brightest being at wave-length 3727, which is presumably the same line as was photographed in the spectrum of the Orion nebula in 1882 by Sir William Huggins.

Five new stars have been recorded in the course of the year, one of them (No. 132) belonging to the year 1899:—

Nova 96 1910 Sagittarii 2	Pickering, *Ast. Nach.*,	**186**, 126.
Nova 97 1910 Cygni	Hinks,	,,	**186**, 126.
Nova 98 1910 Aræ	Pickering,	,,	**186**, 159.
Nova 132 1910 Sagittarii 3	,,	,,	**186**, 319.
Nova 137 1910 Lacertæ	Espin,	,,	**186**, 423.

The spectra of Nos. 96 and 98 show the characteristics of novæ, and that of the former has been studied by Wright at the Lick Observatory (*L.O.B.*, No. 185, vol. vi. 65).

Nova Lacertæ was discovered by Rev. T. E. Espin on December 30, 1910, by visual observations. The spectrum at first exhibited features that were not decisive as to the nature of the star. Later observations prove that it is undoubtedly of nova type; it is now (February) fainter than 9·5 magnitude; the continuous spectrum has become relatively inconspicuous, the nebular line at 5007 is bright and very broad, and many other bright lines are visible. A marked feature from the earliest observations has been the intense brilliancy of the red hydrogen line H_a. Dr. Max Wolf (*Ast. Nach.*, **187**, 46) and Professor Barnard (*Ast. Nach.*, **187**, 63) show that there was previously a star of about 14th magnitude in the position of the Nova.

The spectra of seven *Wolf-Rayet Stars* have been photographed by Duncan at the Lick Observatory (*L.O.B.*, No. 182, vol. vi. 58). Velocity in the line of sight has been deduced in the case of three of them, with the results $-30{\cdot}2$, -8, -28 km/sec.

Special Studies.—The velocity of Orion stars was studied by Frost and Adams in 1903. Frost has given (*Ap. J.*, xxxi. 430) corrections to several of the determinations. They are small, of the order of 1–2 km/sec, and are due to improved recent identification of wave-lengths of some of the lines used in the early determinations.

The bright hydrogen lines of o Ceti have been studied by W.

H. Wright (*L.O.B.*, No. 183, vol. vi.). He has searched for signs of polarisation of the light, but finds no conclusive sign of change of intensity in the components of the triple bright line H_γ when a Nicol prism is inserted in different orientations in front of the slit of the spectrograph.

A memoir by Mr. Baxandall, under the direction of Sir Norman Lockyer, published by the Solar Physics Committee, summarises "Researches on the chemical origin of various lines in solar and stellar spectra." It comprises investigations on (1) differences between the solar spectrum and the following stellar and other spectra: Capella, Arcturus, Sun-spots, α Orionis, Secchi types III. and IV.; (2) the spectrum of ϵ Ursæ Majoris; (3) nitrogen in stellar spectra: (4) a second list of enhanced lines for the elements As, Ba, Be, Cd, Ce, Au, Ir, Li, Te; (5) lines suitable for velocity determinations; (6) list of wave-lengths of marked stellar lines of unknown origin.

Professor Campbell states (*L.O.B.*, No. 173, vol. v. 178) that the observations of the radial velocity of *Procyon*, as determined with the Mills spectrograph, extend over thirteen years, about one-third of the revolution deduced by Dr. Auwers. The radial velocities do not appear to have varied appreciably in a manner to accord with this forty-year period. Thus they seem to support Dr. Auwers' conclusion that the orbit plane is at right angles to the line of sight.

In the same number of the *L.O.B.* Professor Campbell gives a comparison of the recently determined radial velocity of the binary system in the triple system of *Polaris*:—

1899·8	−11·2 km/sec.
1908·7	−17·3 ,,
1909·9	−15·3 ,,

He points out that the minimum is past, and that the velocity of the centre of mass of the binary system is rapidly increasing.

Mr. J. Miller Barr (*R.A.S. Canada*, iv. 261) calls attention to special binary stars β Cephei, XX Cygni, W Ursæ Majoris.

Classification of Stars.—The situation in regard to classification of stellar spectra and views about stellar evolution has in the past year reached a point of intense interest. By reason of the growth of our knowledge of radial motions, a discussion of the relation between velocity and spectral nature is now possible, and it carries weight in a way that was out of the question when the material discussed was small.

Professor Campbell is now able to deal with the radial velocities of about 1050 stars. He has deduced the position of the apex of the Sun's way and the Sun's velocity, and finds $\alpha = 272^\circ{\cdot}0 \pm 2^\circ{\cdot}5$, $\delta = +27^\circ{\cdot}5 \pm 3^\circ{\cdot}0$, and $V = 17{\cdot}8$ km/sec. Using these values to free the radial velocities of the stars from the component of the Sun's motion, he has tabulated the reduced velocities in various ways, with the following results:—

1. The radial velocities of the stars plotted with reference to the number of the stars having certain observed values follow closely the law of accidental errors.

2. The radial velocities do not appear to be a function of the visual magnitudes.

3. The stars of late-type spectra, F5 to M inclusive, 705 in number, have observed radial velocities very nearly 50 per cent. greater than the stars of early-type spectra, O, B, A, to F4 inclusive, 330 in number.

4. When the observed velocities are tabulated with reference to the five divisions of spectral type, (i) O and B inclusive, (ii) A, (iii) F, (iv) G to K inclusive, and (v) M, it appears probable that the velocity of a star is a function of its spectral type. Thus we have

141	stars of type	O	and	B,	with an average velocity of	9·0	km/sec.
?	,,	,,	A	,,	,,	10·0	,,
?	,,	,,	F	,,	,,	14·0	,,
?	,,	,,	G and K	,,	,,	15·0	,,
72	,,	,,	M	,,	,,	16·5	,,

Professor Campbell finds strong evidence confirming Kapteyn's theory of a systematic drift of the stars.

These and other results were summarised by Professor Campbell in the Silliman Lectures delivered in Yale University on January 24 and February 2, 1910, and were communicated in brief abstract to the meeting of the Astronomical and Astrophysical Society of America, held in August at Harvard College Observatory (*Science*, N.S., xxxii. 874).

In a paper on data for stellar classification (*Ap. J.*, xxxi. 258, April 1910), Kapteyn raised the question whether the velocity of a star's motion increases with the age indicated by its spectral type. Starting from Frost and Adams' observation that the helium stars (type B) have exceptionally small velocities ("peculiar," *i.e.* freed from the component due to the Sun's motion), he has tabulated velocities and spectral type for 210 celestial objects with the following results (using the values $\alpha = 269°{\cdot}7$, $\delta = +30°{\cdot}8$ (1875), $v = 20$ km/sec, to eliminate the Sun's motion):—

64	stars of type	B	to	B9	have a velocity of	6·5	km/sec.
18	,,	,,	A	to A5	,,	12·6	,,
17	,,	,,	F	to F8	,,	14·5	,,
26	,,	,,	G	to G5	,,	12·6	,,
55	,,	,,	K	to K5	,,	15·4	,,
6	,,	,,	Ma		,,	19·3	,,
13	Planetary nebulæ				,,	26·8	,,
1	Orion nebula				,,	0·1	,,
8	stars of type	N			,,	13·1	,,
2	,,	,,	L		,,	3·7	,,

Kapteyn has in earlier papers on absorption of light in space (*Ap. J.*, xxix. 46 and xxx. 284) searched for evidence of (*a*) general absorption particularly strong in the violet, such as might be attributed to scattering of light; (*b*) selective absorption, such as widening or strengthening of bands or lines in the stellar spectra. He finds that certain stars which show signs of absorption in the violet end of the spectrum have on the average considerably smaller centennial motions. This is an indication which should be followed up; but it must be remembered that some of the signs of absorption which Kapteyn, with due philosophical reservation, is ready to take as a possible indication of absorption in space, are already indicated in the spectrum of the Sun if we take account of a possible darkening of the continuous spectrum in those parts where the narrow absorption-lines are most numerous. Such a darkening would undoubtedly be detected in the solar spectrum if it were photographed with the small resolving power which is often used in photographing stellar spectra. But if the correlation of which Kapteyn finds evidence is well founded, an interpretation is required.

The situation is thus one of intense interest, whether we regard present indications as pointing to the existence of absorption in space, or to a peculiar distribution of the sources of stellar spectra in space, or to a peculiar distribution of velocities among the stars. It would almost seem as though astrophysicists must develop a kinetic theory applicable to the heavenly bodies, in much the same way as physicists are developing an extension of the kinetic theory of molecules to meet the observed facts relating to the motions of corpuscles. In first thoughts of such a celestial kinetic theory, it seems as if stars of spectral type M should be the lightest bodies, moving quickly on the outskirts of a large swarm of suns, into the middle of which our own system happens to have penetrated.

Variable radial velocity.—Notes on variability of velocity are given for the following stars:—

ψ Persei	Ludendorff, Potsdam	*Ast. Nach.*, **186**, 17
α Canis Majoris	Münch, ,,	,, **186**, 225
α Orionis	Bottlinger, Munich	,, **187**, 33
α Cygni	Lee, Yerkes	*Ap. J.*, xxxi. 177
58 Tauri	,, ,,	,, ,,
B.D. 7° 681 Tauri	,, ,,	,, ,,
θ Pegasi	,, ,,	,, ,,
υ Piscium	Albrecht,	*L.O.B.*, No. 173, vol. v. 174
π Ceti	Moore,	,, ,, ,,
κ Persei	Campbell and Albrecht	,, ,, ,,
b Persei	Curtis,	,, ,, ,,
θ Hydræ	Campbell and Albrecht,	,, ,, ,,
ρ Leonis	Campbell,	,, ,, ,,
α Ursæ Majoris	,,	,, ,, ,,
π 8 Virginis	Albrecht,	,, ,, ,,
η 8 Corvi	,,	,, ,, ,,

D.C. 6501	Wright and Miss Allen,	*L.O.B.*, No. 173, vol. v. 174
χ Ophiuchi	Campbell and Albrecht,	,, ,, ,,
o Draconis	Burns,	,, ,, ,,
ν Draconis	,,	,, ,, ,,
η Lyræ	Albrecht,	,, ,, ,,
τ Draconis	,,	,, ,, ,,
ϵ Draconis	Campbell	,, ,, ,,
θ Cephei	Moore,	,, ,, ,,
σ Cygni	Campbell,	,, ,, ,,
ζ Capricorni	Campbell and Albrecht,	,, ,, ,,
D.C. 9701	Miss Allen	,, ,, ,,
δ Canis Majoris	Wright	*L.O.B.*, No. 173, vol. v. 176
β Crucis	,,	,, ,, ,,
η Centauri	,,	,, ,, ,,
α Lupi	,,	,, ,, ,,
γ Apodis	,,	,, ,, ,,
υ Scorpii	,,	,, ,, ,,
κ Centauri	H. D. Curtis,	*L.O.B.*, 173, vol. v. 178
δ Fornacis	Moore,	*L.O.B.*, 177, vol. vi. 4
27 Canis Majoris	,,	,, ,, ,,
χ Lupi	,,	,, ,, ,,
θ Sagittarii	,,	,, ,, ,,
ζ Sculptoris	,,	,, ,, ,,
λ Hydri	Mrs. Moore,	*L.O.B.*, 182, vol. vi. 55
γ Mensæ	,,	,, ,, ,,
ξ Columbæ	,,	,, ,, ,,
h_1 Puppis	,,	,, ,, ,,
h_2 Puppis	,,	,, ,, ,,
δ Antliæ	Curtis,	,, ,, ,,
θ_1 Crucis	Mrs Moore,	,, ,, ,,
ξ_2 Centauri	J. H. Moore,	,, ,, ,,
h Centauri	Paddock,	,, ,, ,,
d Lupi	,,	,, ,, ,,
ζ Gruis	Wright,	*L.O.B.*, 182, vol. vi. 56
16 Aurigæ	Merrill,	*L.O.B.*, 182, vol. vi. 57
o_2 Canis Majoris	Mitchell,	,, ,, ,,
12 Comæ Berenicis	Merrill	,, ,, ,,
4 Ursæ Minoris	Young,	,, ,, ,,
ι Ophiuchi	Albrecht,	,, ,, ,,
36 Ophiuchi nf	Mrs Moore,	,, ,, ,,
f Draconis	Miss Hobe,	,, ,, ,,
A Sagittarii	Campbell,	,, ,, ,,
α Cygni	,,	,, ,, ,,
25 σ Andromedæ	Frost and Lee,	*Ap. J.*, xxxii. 300
35 Hev. ι Cassiopeiæ	,,	,, ,,
86 ρ Tauri	,,	,, ,,
18 ν Geminorum	,,	,, ,,
42 Camelopardalis	,,	,, ,,
83 ϕ Geminorum	,,	,, ,,

43 γ Cancri	Frost and Lee,	*Ap. J.*, xxxii. 300
22 θ Hydræ	,,	,, ,,
77 σ Leonis	,,	,, ,,
23 Comæ Berenicis	,,	,, ,,
2 η Coronæ	,,	,, ,,
21 ι Serpentis	,,	,, ,,
γ Coronæ	,,	,, ,,
44 π Serpentis	,,	,, ,,
62 γ Ophiuchi	,,	,, ,,
27 ϕ Sagittarii	,,	,, ,,
13 Vulpeculæ	,,	,, ,,
16 Lacertæ	,,	,, ,,
α Pegasi	,,	,, ,,
B.D. 15° 637 Tauri	Barrett,	*Ap. J.*, xxxii. 183
90 c_1 Tauri	,,	,, ,,

Spectroscopic binary stars.—Orbits are given for the following binary systems:—

β Capricorni	Merrill	*L.O.B.*, 178, vol. vi.
β Aurigæ	Baker	*Allegheny Obs.*, i., No. 21
ν Andromedæ	Jordan	,, i., No. 22
ϵ Herculis	Harper	*R.A.S. Canada*, iii. 377
ϵ Herculis	Baker	*Allegheny Obs.*, i., No. 22
1 H Cassiopeiæ	,,	,, ii., No. 4
30 H Ursæ Majoris	,,	,, ii., No. 5
57 Cygni	,,	,, ii., No. 6
θ Aquilæ	,,	,, ii., No. 7
π Andromedæ	Jordan	,, ii., No. 8
μ Herculis	Schlesinger and Baker	,, ii., No. 9
o Persei	Jordan	,, ii., No. 10
α Draconis	Harper	*R.A.S. Canada*, iv. 91
η Bootis	,,	,, ,, iv. 191
ϕ Persei	J. B. Cannon	,, ,, iv. 195
α Orionis	Bottlinger	*Ast. Nach.*, **187**, 33
β Orionis	Plaskett	*Roy. Soc. Can.*, iii. 215

The growth of this branch of astronomical research is well illustrated by the fact that three memoirs dealing with what may be called the statistics of the subject have been published in the past year.

Professor Campbell, in his "Second Catalogue of Spectroscopic Binary Stars" (*L.O.B.*, 181, vol. vi. 17) states that the number of such systems known to us on January 1, 1910, is 306, as compared with 136 on January 1 in 1905. The masterly summary which accompanies this catalogue shows not only what rapid strides are being made towards a comprehensive knowledge of the processes of evolution of the heavenly bodies, but also how much our existing knowledge is coloured by processes of selection exercised unconsciously by observers by virtue of the conditions that determine

ease of discovery of multiple systems. A few dicta culled from Professor Campbell's paragraphs will serve to indicate the points he has summarised. "The excentricity is seen to be in general a function of the period of revolution." "The secondary members are in general of considerably smaller mass than their primaries." "Visual doubles clearly abhor the O and B types [of spectrum], and visual double stars of relatively short periods clearly abhor M and N types." "The β Lyræ Variables are Algols of an extreme type." "The fainter and earlier type spectrum belongs to the less massive member of the system [in the case of sixty-two close binary systems in which both spectra are decipherable]." "The spectrographic observations at the Yerkes Observatory have established that at least one star in three, on the average, of very early-type stars is a spectroscopic binary." "The Lick Observatory observations . . . . confined more largely to the middle and later stellar types . . . . show that one star in six is a binary." Aitken's double-star investigations show that one star out of every eighteen is a visual binary."

The papers of Ludendorff (*Ast. Nach.*, **184**, 373, and **185**, 59) and of Schlesinger (*Allegheny Observations*, vol. i., No. 20) deal with discussions of a similar nature. It would hardly be satisfactory to attempt abridgment of them here, but their value is very great, inasmuch as they concentrate attention not only on the points where generalisations seem to be legitimate, but also on those aspects of the advance where special evidence is urgently needed. All three summaries may be advantageously studied in connection with a paper by H. N. Russell on the "Origin of Binary Stars" (*Ap. J.*, xxxi. 185).

D. F. Comstock calls attention to a simple criterion for the detection of anomalies in the orbits of spectroscopic binary systems (*Ap. J.*, xxxi. 364).

Comets.—Attention should be called to Professor Fowler's paper on the interpretation of cometary spectra in general (*M.N.*, lxx. 176 and 484, together with notes of Backhouse and Fowler (*M.N.*, lxx. 622 and 623).

Observations on the spectrum of the Daylight Comet 1910*a* are recorded by Newall (*M.N.*, lxx. 459), by Wright (*L.O.B.*, 174, vol. v. 179), and by Albrecht (*L.O.B.*, 174, vol. v. 183).

Observations on the spectrum of Halley's Comet are published by—

Evershed (*M.N.*, lxx. 605).
Butler (*Proc. R.S.*, **84**, 523).
Schwarzschild (*Ast. Nach.*, **185**, 135).
Slipher (*Lowell Obs. Bull.*, No. 47).
Riccò (*Boll. Acad. Catania*, xii. and xiii., 1910).

Stellar Temperatures.—C. G. Abbot having criticised (*Ap. J.*, xxxi. 274) the work of Wilsing and Scheiner on temperature determinations, the authors reply (*Ap. J.*, xxxii. 130).

Instruments and Reduction.—In possible modes of utilising the objective prism and objective grating for determining stellar

velocities in the line of sight, Professor Pickering (*H.C.O. Circ.*, No. 154; *Ap. J.*, xxxi. 372) and Professor R. W. Wood (*Ap. J.*, xxxi. 376) report advances depending on trials of ray-filters for producing narrow absorption-lines. A solution of chloride of neodymium has been used with some promise of success.

Professor Frost comments on the precision attainable in determinations of radial velocity (*Ap. J.*, xxxi. 377).

Dr. Eberhard has a valuable paper on the bending of spectrographs (*Zeitschr. Instrumentenkunde*, xxx., Feb. 1910).

J. S. Plaskett calls attention to the need of great accuracy in the collimation of correcting lenses used in conjunction with stellar spectrographs (*Ap. J.*, xxxii. 243). And the same writer also contributes a paper on the probable errors of radial velocity determinations (*Ap. J.*, xxxii. 230), and a paper on slit width and errors of measurement in such determinations (*Roy. Soc. Can.*, iii. 209). The same writer's Report on Astrophysical work carried out at the Dominion Observatory, Ottawa, in 1898, was issued from the Government Printing Bureau in the past year, and contains a full account of researches on the binary systems ι Orionis, ψ Orionis, η Virginis, and θ Aquilæ.

F. Schlesinger gives a description of the Mellon spectrograph with single prism, used in attachment to the Keeler Memorial Telescope (reflector). H. F. N.

Star Catalogues.

There have been a comparatively large number of star catalogues published during the year. The titles of these and some of the salient points of each are given in the following paragraphs:—

Boss's Preliminary General Catalogue of 6188 *Stars for the Epoch* 1900·0.—This catalogue is actually part of the larger one of 25,000 stars on which Professor Boss has been engaged for some years; but thinking it would be useful for the progress of science to make some part of his results available at a date earlier than that of the whole publication, he has issued this preliminary catalogue of 4030 stars of the sixth magnitude and brighter, together with 2158 other stars fainter than this limit, selected for certain reasons. The primary object of the catalogue is to give the proper motions of the stars as they result from a precise discussion of all readily available observations in each case. The material made use of as data consists of the positions of stars found in a search through all published catalogues, beginning with Bradley's observations, as reduced by Auwers, and extending to the Cape Catalogue of 1906, some observations existing in the form of annual catalogues being omitted. These observations were corrected for all systematic errors, reduced and collated, and finally the columns of the main catalogue contain the Right Ascension and Declination of the stars already specified reduced to epoch 1900, the actual epoch of

observation of any particular star being some date in the last half of the nineteenth century, with a deduced proper motion in each element for each star. The appendices contain ephemerides of polar stars, that is to say, the mean positions in every fifth year from 1900 to 1925, and also tables of systematic corrections to all the catalogues used, which will doubtless be found of value.

Catalogue of Right Ascensions of 1716 *Stars for the Epoch* 1820·0, *from observations made by W. Struve with the Dollond Transit Instrument at Dorpat in the years* 1818–1822. — A hundred years ago, in the year 1811, Wilhelm Struve, then nineteen years of age, was a pupil in the class of Astronomy at the Dorpat University. The Professor, Huth by name, was not able, on account of ill-health, to take great interest in the Observatory of the University, but permitted his pupil Struve to do with it as he wished. The Observatory was then not very adequately equipped, and among the instruments was a transit instrument by Dollond, with an object-glass of 115 mm. aperture and 2·233 metres focal length, which had not only never been used, but was not completely finished and mounted. Struve did the necessary work with his own hands, and used the instrument until the year 1822, when the Reichenbach-Ertel transit-circle was added to the observatory equipment. Struve's early observations with the Dollond instrument are given in volume i. of the Dorpat Observations, where they are collected into a small catalogue: those made in the years 1818–1822 are contained in vols. ii. and iii. These last, with some observations hitherto unpublished, made in the early months of the year 1822, have been reduced under the auspices of Professor Ludwig Struve, Director of the Observatory at Charcow, to form the catalogue above described, which appears as a volume of the publications of the Dorpat Observatory. The stars contained in the catalogue comprise (1) circumpolar stars between the declinations +70° and +80°; (2) stars north of declination +45°, which had been observed by Struve above and below Pole for determinations of parallax and the constant of aberration; (3) double stars observed to determine the difference of Right Ascension of the components, of which there are a great many in the catalogue. The volume of the Dorpat Publications (xxii.) contains, besides the final catalogue, the original observations, with their complete reduction.

Catalogue of 3461 *Stars in Declinations* 69° 40′ *N. to* 75° 20′ *N.* (1855) *for the Epoch* 1905·0.—This is a second edition of a zone of the *Astronomische Gesellschaft* series; the first, however, being not yet published, and the main catalogue is in exactly the same form as the other catalogues of the series, though the places are reduced to a different epoch. This zone 70°–75° N. was originally allotted to the observatory at Dorpat, and the necessary observations were made there between the years 1870 to 1882, but these observations did not exactly follow the programme laid down for this series of catalogues, and the zone has been re-observed at the Imperial Observatory at Berlin in the years 1905–

1908. This catalogue, which is known as Berlin C, has been made under the direction of Herr L. Curvoisier, and contains about 500 stars which are not in the Dorpat Catalogue of the zone. The catalogues being reduced to exactly the same system, and the epochs of observation being separated by about thirty years, there would appear to be material easily available for determination of proper motion ; and in the appendices, for every star common to the Berlin C and the Dorpat Catalogue the difference of R.A. and declination of the two catalogues is given, and similarly for the stars common to the Berlin Catalogue and the A.G. Catalogue of Christiania or Kasan, which it overlaps at its south or north boundary. From these differences the proper motions of 80 stars have been deduced, the cases being those in which the star appears in some other catalogue.

Catalogue of 3458 *Stars for Epoch* 1875·0 *by Johann Palisa* (*Vienna Annals*, vol. xix.).—This catalogue is compiled from transit-circle observations made at the Observatory of the Imperial University of Vienna in the years 1843–1879. The stars were selected for observation for various reasons, some having been required for the reduction of comet or planet observations, and a large proportion being those which were used by Oeltzen in the reduction of Argelander's observations of stars between declinations 15° to 20° N. ; a relatively small number are stars of Lalande's catalogue fainter than magnitude 9. The observations were reduced with the star places of the *Nautical Almanac* as fundamental, corrections being applied to these when necessary to reduce the places of different years to a homogeneous system. Since the epoch is the same as that of the Astronomische Gesellschaft Catalogues, it is easy to make a comparison ; and the seconds and decimals of a second of the places of the stars from the catalogues of this series, when available, are given in the columns of this work now being mentioned.

Catalogue de l'Observatoire de Bordeaux.—This catalogue contains the position of 6999 stars for the equinox of 1890·0 of the zone comprised sensibly between the south declinations 15° and 20° based on observations made with the meridian circle of Bordeaux in the years 1881–1895. The total number of stars is made up of 6530 stars of the Catalogue of Argelander's Zones published by Dr. E. Weiss in 1850, together with 429 stars which were not observed by Argelander. Omitting 17 of the fundamental stars, the average number of observations on which a catalogue-place depends is 2·1 ; nearly a thousand stars were observed more than twice, and there are in the catalogue between five and six hundred positions depending on one observation only.

The observations of Right Ascension were made by Eye and Ear. The probable error of a single observation is given as in Right Ascension $\pm 0^{s}\cdot 054$, which is equivalent to $\pm 0''\cdot 773$, and in Declination $\pm 0''\cdot 662$. The positions of the fundamental stars used for clock error and for the reduction of Declination were taken from the *Connaissance des Temps*, with corrections deduced from

observations made at the Paris Observatory in the years 1868 to 1876 applied. There are thirty-five stars in the catalogue which are also in Newcomb's Fundamental Catalogue, and comparison of the Bordeaux places of these stars having been made with those of Newcomb, the arrangement in order of R.A. does not show any difference which can be considered periodic, and the mean of the differences weighted according to the number of observations gives corrections necessary to reduce the Bordeaux places to Newcomb of $+0^{s}\cdot043$ and $-0''\cdot03$ in the two elements respectively.

Edinburgh Catalogue of 2713 *Zodiacal Stars for Epoch* 1900.—The stars of this catalogue are contained in a list of 2798 prepared by Sir David Gill, as suitable for reference stars in heliometer observations of the major planets. The observations were made at the Royal Observatory, Edinburgh, in the years 1898 to 1908, under the direction of Professor Copeland and Professor Dyson, a self-registering micrometer, moved by hand, being used for observations of Right Ascension after the beginning of 1907. A comparison is given in the Introduction of the Right Ascensions as found by each of the two observers with the Right Ascensions of the same stars as given in the Cape Zodiacal Catalogue, the stars being divided into groups according to magnitude, which affords information as to the possibility of eliminating magnitude equation by means of a self-recording micrometer. In the case of each observer observing transits over fixed wires, the difference Edinburgh – Cape was considerably larger for 7th and 8th magnitude stars than for 5th and 6th. With the recording micrometer these differences were practically the same for stars of all magnitudes.

The catalogue is of the form usual to such works. Precessions, proper motions, and magnitudes of the stars are given, taken directly from the Cape Zodiacal Catalogue.

A Catalogue of 2047 *Stars between* 31° *and* 33° *South Declination for the Equinox* 1900·0, *from observations made at the Perth Observatory, Western Australia.*—The construction of this catalogue was necessary for the Astrographic work, zone $-31°$ to $-41°$, which is being done at the Perth Observatory, for the stars it contains have been selected as reference points for the reduction of the catalogue plates at the rate of three per square degree. The method of its construction is similar to that proposed by the Committee appointed at the International Conference at Paris for making the Standard Catalogue which is to serve as basis for all future sky surveying. Mr. Cooke, the Director of the Perth Observatory, instead of making a primary catalogue by determining his own equator and reference points, chose Auwers' "Fundamental Catalog für Zonenbeobachtungen am Sudhimmel" as the basis of reduction, and with the stars of this catalogue for fundamentals made a catalogue of 420 secondary standard stars for the whole zone $-31°$ to $-41°$ which formed vol. i. of the Publications of the Perth Observatory, and with these secondary standards the *étoiles de repère* are being observed differentially zone by zone. The method of these zone observations was described by Mr. Cooke in

Monthly Notices, vol. lxvi. p. 347. Vol. ii. of the Publications comprised the zone -39° to -41°; vol. iii. the zone -33° to -35°. The observations of the present zone -32° to -33° appear to have been made, and their reduction completed very expeditiously, for the star positions depend on at least three observations in almost every case. Right Ascensions are given to hundredths of a second, Declinations to tenths, and the precessions in each element to the next decimal place respectively. The appendix to the small volume is of quite a novel kind. It consists of ruled and partially filled-in tabular forms, which are to be used at some future time when the places of the standard stars on which the catalogue depends are better known. When this time arrives the blanks will be filled in, and the filled-in figures will give very readily corrections to be applied to each star of this catalogue.

Munich Catalogue of 1436 *Stars.*—This catalogue, with the details of its preparation, forms vol. iv. of the Munich Observations, new series, and was published in 1909. It contains the places for epoch 1900·0 of 1436 stars, chiefly near the zenith, and most of them as bright as the sixth magnitude, derived from observations made in 1894–1901 with the meridian-circle of the Observatory, the observations of Right Ascension being made with a registering micrometer. The catalogue was compiled by Dr. Oertel, under the direction of Professor Seeliger, and is evidently of high precision, the number of observations on which each star place depends being in the mean about 12. This will doubtless be found of value; and a list of the proper motions of most of the stars in the catalogue, as given by various authorities, should prove useful.

Mention must also be made of a catalogue of the Right Ascensions of 4066 stars, the majority of them being the Zodiacal Stars in Sir David Gill's list, derived by Herr Fritz Cohn from observations made by himself, with an automatic registering micrometer, at the University Observatory, Königsberg. The Repsold meridian instrument, with which the observations were made, being reversible, was used in both positions, and the discussion of the results in the two positions, with other details of the compilation, is given with much completeness. The catalogue forms fascicule 42 of the Königsberg Observations. H. P. H.

The Astrographic Chart and Catalogue.

Following the detailed report of the state of this work given last year, there is little to add with respect to 1910, and a statement of the publications of the year may be a sufficient report of progress. Volume V. of the Oxford Catalogue, which is the sixth of the series, has been distributed, and the publication of the rectangular co-ordinates of the stars in this zone which covers the sky from declination $+24^\circ$ to $+32^\circ$ is thereby completed. A

seventh volume containing discussions is being prepared. Adding the figures printed on the title-pages of the six volumes, it is found that the total number of entries is 394,374, and as the zone from $+25^\circ$ to $+31^\circ$ is in duplicate, and there is some overlapping of consecutive plates of the same zone, the actual number of stars in the Oxford zone may be taken as about half this total. The Catania Observatory has published another part similar to those previously issued from this Observatory, the last of which is dated 1909, so that this zone appears to be proceeding rapidly. The Catania Catalogues show the right ascension and declination of stars deduced from individual images to $0^s{\cdot}001$ and $0''{\cdot}01$ in each co-ordinate respectively.

Volume V. of the Potsdam Catalogue was also published in 1910. The plates taken and reduced at this Observatory have not been arranged in the volumes in any particular order, but the earlier volumes have each contained a few plates from all or several of the zones $+32^\circ$ to $+39^\circ$. Volume V. contains the measures of 47 plates of declinations $+32^\circ$ or $+33^\circ$, and the first of these zones is now complete. The Potsdam Catalogues give, besides the rectangular co-ordinates, the R.A. to seconds and the declination to tenths of a minute, and also a photographic magnitude of each star, these last being compared with the corresponding magnitude of the *Bonn Durchmusterung* when such are available, the differences being summarised plate by plate in the introduction to the various volumes.

The progress of the Chart may be estimated by means of the following table, which gives the numbers of enlarged copies of chart-plates distributed by different observatories up to December 31. It will be remembered that the Greenwich zone is already complete.

Algiers	359	San Fernando	265
Bordeaux	140	Tacubaya	153
Brussels	9	Toulouse	191
Paris	386		

It will not be out of place to record here, with regret, the death of M. Felipe Valle, who had been Director of the Tacubaya Observatory since 1900, and to whom the active progress of the zone 10° to 16° S. decl. allotted to that observatory is largely due.

H. P. H.

The "Astrolabe à prisme."

The publication by MM. Claude and Driencourt of a considerable treatise on the use of this instrument is noteworthy in two respects. The instrument itself is simple and beautiful; the method is an interesting example of that class of methods which has received much attention in recent years.

The determination of latitude and time from three equal altitudes of known stars is a well-known text-book method due to

Gauss, who worked it with a clamped sextant. Chandler's almucantar embodied an extension of the principle; all observations with the almucantar are made on the same horizontal small circle, which passes through the pole. For work in the field similar ideas have been developed by Wade * in Egypt and by W. E. Cooke † and Bartlett ‡ in Australia, using a theodolite clamped at the altitude of the pole, and readjusted, therefore, for each place.

The *astrolabe à prisme*, on the other hand, employs the horizontal circle of altitude 60°. An equilateral prism is carried over the objective of a horizontal telescope. The base of the prism is normal to the axis of the telescope, and the edges are horizontal. In front of the prism, and a little below, is a dish of mercury. The telescope, prism, and mercury bath turn on a vertical axis, and are directed in the azimuth of the star to be observed. As the star approaches the altitude 60°, its light enters the upper inclined face of the prism normally, is totally reflected from the lower face, passes normally through the base, and enters the lower half of the objective. A second bundle of rays is reflected upwards from the mercury, enters the lower face of the prism normally, and, after total reflection, passes through the upper half of the objective. The two resulting images of the star coincide when the star is at an altitude rigorously equal to the angle of the prism.

Messrs. Claude and Driencourt give a very complete account of the instrumental refinements and methods of adjustment which have been evolved in the adaptation of the instrument to precise geodetic work. Without any nicety of construction, however, it is easy to exceed the ordinary accuracy of field observations. In 1905 a home-made instrument in the observatory of the Jesuit Fathers at Buluwayo gave excellent results.

The preparation of an observing programme and the reductions are, at first sight, complicated. They can be facilitated by auxiliary tables and graphical processes; and that they do not really involve grave difficulties is proved by the fact that they have been used with success by the French surveyors on the Congo-Cameroon boundary, and more recently in the remeasurement of the meridian arc in Ecuador. The instrument has thus passed its experimental stage, and has established its position in survey of the higher order. A. R. H.

The Eötvös Torsion Balance.

By the improvements made by Baron Eötvös in the torsion balance, and by its conversion into a field instrument, a new power is placed in the hands of the geodesist, and the investigation of the local variation of gravity on the Earth's surface is both facilitated and rendered more precise. A short account of the instrument will not be out of place here.

* *M.N.*, lxiv. 107. † *M.N.*, lxiii. 156, lxiv. 70.
‡ *M.N.*, lxx. 197.

Imagine a torsion balance of the ordinary form, *i.e.* a light rod with weights at each end, hung horizontally by a fine thread attached at its middle point, placed at a station where there is no local attraction. The thread will hang vertically downward in the direction of the resultant force of gravitation and, the distribution of the earth masses in the neighbourhood of the instrument being symmetrical, the beam is under no constraint towards any particular azimuth, so that, suppose the beam to have come to rest in any position, if the torsion head, carrying the thread, be turned through any angle, the beam will turn through the same angle.

If, now, the symmetrical distribution of gravity is disturbed, say by the presence of an attracting mass of rock, giving rise to a horizontal component in the force of gravity, the thread will still hang vertically, but this "vertical" will be inclined to the original direction at a small angle, called the deviation of the plumb line. The beam can no longer assume any azimuth with equal facility. There are now two directions, one when the beam is in the line joining the instrument with the centre of action of the horizontal force, and the other when it is at right angles to this line, where the beam can come to rest with the thread untwisted. In any other azimuth there will be a residual twisting of the thread, so that if the torsion head be now turned through any angle the beam will not in general follow it through the same angle.

By turning the torsion head through successive angles of 45°, 90°, 135°, etc., and by noting the corresponding positions at which the beam comes to rest, we can map out the rates of change of the gravitational forces along any selected horizontal axis, and determine the direction of the resultant horizontal component.

[Expressed analytically; if z be the axis vertically downward from the origin, taken at the centre of the beam, x, y any two horizontal axes mutually at right angles, and u the Earth's potential at any point, then the instrument determines the values at the origin of—

$$\frac{d^2u}{dxdz}\,;\ \frac{d^2u}{dydz}\,;\ \left(\frac{d^2u}{dy^2}-\frac{d^2u}{dx^2}\right)\,;\ \frac{d^2u}{dxdy}\,.$$

By pendulum observations the value of $\frac{d^2u}{dx^2}$ can be found; and as at any point outside the Earth $\frac{d^2u}{dx^2}+\frac{d^2u}{dy^2}+\frac{d^2u}{dz^2}=0$, it is thus possible to separate $\frac{d^2u}{dy^2}$ from $\frac{d^2u}{dx^2}$ so that all the second differentials of the potential are determined.]

It will thus be seen that the essential features of the method are extremely simple, and involve no new principle. The great achievement of the inventor lies in the transformation of an instrument of an ultra-sensitive nature, only capable of use in a laboratory with every possible shielding from external disturbance, into a portable instrument adapted for use in the field.

The extreme minuteness of the quantities revealed by the torsion balance can best be realised when we remember that we are, in effect, measuring the torsional couple due to the difference in the attraction of the horizontal component of gravity upon the weights at the two ends of the beam respectively. The horizontal component is already itself very small, except in altogether abnormal places, so that, without going into figures, it is sufficiently obvious that this difference is near the limits of instrumental observation. The close accord of the results actually obtained by Eötvös in the field, both among themselves and in comparison with those arrived at in other ways, shows that the measurement lies well within the power of the instrument as designed by him.

Hitherto there have been two methods available for determining the local variation of gravity, one by pendulum observations, and the other by a comparison, over a large number of stations, between geodetic and astronomical positions. The torsion balance is now available to supplement these, and is capable of giving information beyond the power of the older methods.

A special investigation, to which the apparatus has been applied by its inventor, is to answer the question as to within what limits the constant of gravitation is the same for all bodies. If it is not, the direction of the apparent vertical will vary with the material of the plumb-bob, since the observed weight of any body is the resultant of two forces, the attraction which for two different bodies would have the same direction, but, on this assumption, a different intensity, and the centrifugal force which would have the same direction and the same intensity for every body.

Previous observations with the pendulum had shown that there was no difference greater than 1/60,000; with the torsion balance Eötvös has shown that any difference cannot exceed 1/200,000,000. It will be remembered that Laplace investigated this question astronomically by comparing the Sun's attraction upon the Earth and Moon respectively, and found that any difference was smaller than 1/1,000,000. His calculations remade with the data now available give 1/50,000,000. E. H. H.

List of Public Institutions and of Persons who have contributed to the Library, etc. since the last Anniversary.

The Commonwealth of Australia.
The Dominion of Canada.
His Majesty's Government in India.
The New Zealand Government.
The Lords Commissioners of the Admiralty.
The French Government.
The Italian Government.
British Association for the Advancement of Science.
British Astronomical Association.
British Horological Institute.
Geological Society of London.
Institution of Electrical Engineers.
International Union for Solar Research.
London University College.
Meteorological Office.
National Physical Laboratory.
Physical Society of London.
Royal Meteorological Society.
Royal Observatory, Greenwich.
Royal Photographic Society of Great Britain.
Royal Society of London.
Solar Physics Observatory.
Belfast Natural History and Philosophical Society.
Birmingham and Midland Institute Scientific Society.
Birmingham Natural History and Philosophical Society.
Cambridge Observatory.
Cambridge Philosophical Society.
Cardiff, Astronomical Society of Wales.
Chatham, Royal Engineers' Institute.
Dublin, Royal Irish Academy.
Dublin, Royal Society.
Durham, University Observatory.
Edinburgh, Royal Observatory.
Edinburgh, Royal Society.
Liverpool Astronomical Society.
Liverpool Literary and Philosophical Society.
Liverpool Observatory.
Manchester Literary and Philosophical Society.
Manchester, Municipal School of Technology.
Oxford, Ashmolean Natural History Society.
Oxford, Radcliffe Observatory.
Oxford, University Observatory.
Rugby School Natural History Society.

Stonyhurst College Observatory.
Southport, Fernley Observatory.
Algiers Observatoire.
Allegheny Observatory.
Amsterdam, Koninklijke Akademie van Wetenschappen.
Arcetri, Reale Osservatorio.
Athens, Observatoire National.
Bamberg, Remeis-Sternwarte.
Barcelona, Sociedad Astronomica.
Basel, Naturforschende Gesellschaft.
Basel Universität.
Batavia, Royal Magnetical and Meteorological Observatory.
Batavia, Koninklijke Natuurkundige Vereeniging.
Berlin, Deutsche Physikalische Gesellschaft.
Berlin, Königlich Astronomisches Recheninstitut.
Berlin, Königlich Preussiche Akademie der Wissenschaften.
Berlin, Königliche Sternwarte.
Berne, Universität.
Besançon, Observatoire National Astronomique.
Bologna, Osservatorio della R. Università.
Bologna, Reale Accademia delle Scienze.
Bombay, Government Observatory.
Bordeaux, Commission Météorologique du Gironde.
Bordeaux, Observatoire.
Bordeaux, Société des Sciences Physiques et Naturelles.
Boston, American Academy of Arts and Sciences.
Brazil, Sociedade Scientifica de São Paulo.
Brussels, Académie Royale des Sciences de Belgique.
Brussels, Société Belge d'Astronomie.
Budapest, Königl. Ung. Reichsanstalt für Meteorologie und Erdmagnetismus.
Buda Pest, Magyar Tudományos Akadémia.
Canada, Geological Survey.
Cape of Good Hope, Royal Observatory.
Cape Town, Royal Society of South Africa.
Cape Town, South African Association for the Advancement of Science.
Catania, Reale Osservatorio.
Catania, Società degli Spettroscopisti Italiani.
Christiania, Universitäts Observatorium.
Copenhagen, Kongelige Danske Videnskabernes Selskab.
Cordoba, Oficina Meteorológica Argentina.
Cracow, Académie des Sciences.
Dorpat (Jurjew), Kaiserliche Universitäts-Sternwarte.
Egypt, Survey Department.
Geneva Observatoire.
Geneva, Société de Physique et d'Histoire Naturelle.
Göttingen, Königliche Gesellschaft der Wissenschaften.
Granada, Observatorio Astronomico, Geodinamico et Meteorologico.

Groningen, Astronomical Laboratory.
Halle, Kaislerlich Leopoldinisch-Karolinische Akademie.
Hamburger Sternwarte in Bergedorf.
Harvard College Astronomical Observatory.
Heidelberg, Astrophysikalisches Observatorium.
Heidelberg, Astronometrisches Institut.
Helsingfors, Fiska Vetenskaps Societet.
Helsingfors, Institut Météorologique Central.
Helwân Observatory, Cairo.
India, Astronomical Society.
India, Survey Department.
Japan, Astronomical Society.
Johannesburg, Transvaal Observatory.
Kasan, Observatoire de l'Université Impériale.
Kiel, Königliche Sternwarte.
Ksara [Syria], Observatoire.
Kodaikánal Observatory.
Königsberg, Königlich Universitäts Sternwarte.
La Plata, Observatorio.
Leiden, Sterrewacht.
Leipzig, Astronomische Gesellschaft.
Leipzig, Fürstlich Jablonowski'sche Gesellschaft.
Leipzig, Königlich Sächsische Gesellschaft der Wissenschaften.
Lick Observatory.
Lisbon, Sociedade de Geographia.
Lowell Observatory.
Lund, Astronomiska Observatorium.
Madrid, Instituto Central Meteorologico.
Madrid, Observatorio Astronomico.
Madrid, Real Academia de Ciencias.
Manila, Philippine Weather Bureau.
Mantua, Reale Accademia Virgiliana.
Mauritius, Royal Alfred Observatory.
Mexico, Sociedad Cientifica "Antonio Alzate."
Milan, Reale Osservatorio di Brera.
Moncalieri, Osservatorio Centrale del R. Collegio Carlo Alberto.
Montpellier, Académie des Sciences et Lettres.
Moscow, Société Impériale de Naturalistes.
Mount Wilson, Solar Observatory.
Münich, Königlich Bayerische Akademie der Wissenschaften.
Münich, Königliche Sternwarte.
Naples, Osservatorio.
Naples, Reale Accademia delle Scienze.
Natal Observatory.
Neuchâtel, Observatoire Cantonal.
New York, Observatory of Columbia University.
Nice, Observatoire.

Nizbor [Bohemia], Observatoire Astrophysique.
Nova Scotian Institute of Science.
Oporto, Academia Polytechnica.
Ottawa, Dominion Astronomical Observatory.
Padua, Observatorio Astronomico della R. Università.
Paris, Académie des Sciences.
Paris, Bureau des Longitudes.
Paris, Bureau International des Poids et Mesures.
Paris, Congrès Astrophotographique International.
Paris, École Polytechnique.
Paris, Observatoire.
Paris, Société Astronomique de France.
Paris, Société Mathématique de France.
Paris, Société Philomathique.
Perth Observatory, Western Australia.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Pola, Hydrographisches Amt der K.u.K. Kriegs-Marine.
Potsdam, Astrophysikalisches Observatorium.
Potsdam, Central Bureau der Internationalen Erdmessung.
Potsdam, Königlich Preussische Geodätische Institut.
Prague, K. K. Sternwarte.
Pulkovo, Observatoire Central Nicolas.
Queensland, Royal Geographical Society.
Rio de Janeiro, Observatorio.
Rome, Reale Accademia dei Lincei.
Rome, Reale Osservatorio del Collegio Romano.
Rome, Società Italiana delle Scienze.
San Fernando, Instituto y Observatorio de Marina.
San Francisco, Astronomical Society of the Pacific.
Santiago de Chile, Observatorio Astronomico.
St Petersburg, Académie Impériale des Sciences.
Stockholm, Kongliga Svenska Vetenskaps-Akademie.
Sydney, Royal Society of New South Wales.
Tacubaya, Observatorio Astronómico Nacional.
Talence (Gironde), Observatoire.
Tiflis, Physikalisches Observatorium.
Tokyō, Observatoire Astronomique.
Toronto, Canadian Institute.
Toronto, Royal Astronomical Society of Canada.
Toronto University.
Tortosa, Observatorio del Ebro.
Toulouse, Académie des Sciences.
Toulouse, Commission Météorologique de la Haute Garonne.
Toulouse, Observatoire Astronomique.
Transvaal, Meteorological Department.
Turin, Reale Accademia delle Scienze.
Turin, Reale Osservatorio Astronomico.
Turin, Società Astronomica Italiana.
Uccle, Observatoire Royale de Belgique.

United States Coast and Geodetic Survey.
Upsala, Kongliga Vetenskaps-Societet.
Upsala, Observatorium.
Vienna, Kaiserliche Akademie der Wissenschaften.
Vienna, K.K. Universitäts-Sternwarte.
Vienna, von Kuffner'sche Sternwarte.
Washington, Carnegie Institution.
Washington, Navy Department.
Washington, Philosophical Society.
Washington, Smithsonian Institution.
Washington, United States Naval Observatory.
Wellington, New Zealand Institute.
Yale University Observatory.
Yerkes Observatory.
Zi-Ka-Wei, Observatoire Astronomique de Zô-Sè.
Zürich, Naturforschende Gesellschaft.
Zürich, Schweizerische Geodätische Commission.
Zürich, Schweizerische Meteorologische Centralanstalt
Zürich, Sternwarte.
Editors of the "American Journal of Mathematics."
Editors of the "American Journal of Science."
Editor of the "Astronomical Journal."
Editor of the "Astronomische Nachrichten."
Editor of the "Astronomischer Jahresbericht."
Editors of the "Astrophysical Journal."
Editor of the "Athenæum."
Editors of the "Bulletin des Sciences Mathématiques."
Editor of the "English Mechanic."
Editor of "Himmel und Erde."
Editor of "Indian Engineering."
Editor of the "Journal Astronomique."
Editor of "Knowledge."
Editor of "Nature."
Editor of the "Naturwissenschaftliche Rundschau."
Editors of "The Observatory."
Editors of "Popular Astronomy."
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Prof. A. Wolfer.
Herr H. von Zeipel.

ADDRESS

Delivered by the President, Sir David Gill, K.C.B., on presenting the Gold Medal of the Society to Dr. P. H. Cowell.

On this occasion the Gold Medal of the Society has been awarded by your Council to Dr. Cowell, the recently appointed Superintendent of H.M. Nautical Almanac Office, for his Contributions to the Lunar Theory and Gravitational Astronomy.

If one studies the list of persons and of subjects for which this medal has been awarded in the past, it will be seen that the choice of our Laureates has been limited neither by considerations of nationality nor by preference for particular departments of Astronomy.

Last year I had the honour of presenting our medal to Professor Küstner of Bonn, one of the most eminent of living practical astronomers.

To-day the Medal goes to a Fellow of our Society who has no pronounced taste for the processes of practical astronomy, but who, we all believe, is destined to take a very distinguished place in the future of mathematical astronomy and celestial mechanics.

Amongst the great geometers of the world we find men of various tastes and capacity—those to whom the symmetry and elegance of algebraic results are everything, others to whom the supreme value of their work lies in its capacity for translation into methods for numerical computation.

Dr. Cowell, fortunately for us and for astronomy, represents the second of these types. His delight is not only to conceive new methods of research, but to find satisfaction in their practical application to astronomical problems—as did Laplace and his successors in the great French School of Mathematical Astronomy.

Educated at Eton, where he was awarded the Tomline Mathematical Prize, he gained by competition an entrance scholarship at Trinity College, Cambridge, in 1889. There, in 1891, he won the Sheepshanks exhibition in Astronomy, and graduated as Senior Wrangler in 1892.

In 1894 the Isaac Newton Studentship was awarded to him, and he obtained a Fellowship at Trinity College in the same year.

His fellowship-dissertation (*American Journal of Mathematics*, vol. xviii., No. 2) consisted of the calculation, by G. W. Hill's methods, of the inclinational terms of the Moon's motion as far as the third order; and also, incidentally, the computation of the principal part of the motion of the node, and that part of it which contains the square of the inclination as a factor.

Our Medallist remained at Cambridge, pursuing the same line of thought and work. There, in 1894, he made the acquaintance of Professor E. W. Brown, who in that year had already completed the calculation of the elliptic terms of his lunar theory, and had come from America to Cambridge on a prolonged visit. The men were kindred spirits, and Dr. Cowell read the proof sheets of his friend's Text-book on the Lunar Theory, then going through the press, and has ever since minutely followed Professor Brown's work.

In 1896 our Medallist was selected by Sir William Christie as the Second Chief Assistant at the Royal Observatory, Greenwich, and he left Cambridge in April of that year to take up his new duties.

Here an entirely new class of work awaited him, such as general administration, the supervision of observations, the adjustment of instruments, etc.,—work, in fact, entirely outside his previous experience, and which did not appeal to his natural tastes so strongly as did that in which he had been formerly engaged. After devoting some years to these duties, and introducing improved methods of computation in various departments of the Observatory, he finally devoted himself more and more to those departments of astronomy for which he had a strong predilection.

He applied himself in the first place to an analysis of the outstanding discordances between Hansen's Tables of the Moon and the Greenwich Meridian Observations. His object in this research was to correct the coefficients of the periodic terms in the Moon's motion, of which Hansen had taken account, and to detect the existence of other periodic terms which had not been included in the construction of the tables. The observations minutely considered in this research extend over the period 1847–1901; for terms of longer period than two months, or for the separation of two terms of nearly coincident period, the observations from 1750 to 1851 were also included.

The marked original features of this discussion are—

(1) The labour-saving devices which permitted the analysis to be extended to all the inequalities, instead of the comparatively limited number of them examined by previous investigators.

(2) The method of taking account of the unequal distribution of the observations during the lunation—that is to say, the absence of observations near new moon.

Briefly described, the method was as follows:—

The discordance (C – O) was entered in the calculation form, for every observation, in a position that implied its date. That position therefore implied the numerical value of every argument with respect to which the data were analysed. To pass from one line to the next in the table of entry implied a lapse of one exact lunar day ($24^h\ 50^m$ nearly); so that, with 40 lines on each sheet of paper, 10 sheets covered a period of 414 days = 14 lunations = 15 anomalistic months = 13 periods of the "Evection." This period was therefore taken as the unit for analysis. Some previous investigators had used the year in a similar manner, but the unit

employed by Dr. Cowell facilitates the arrangement of the calculation, and presents other numerical advantages.

The observations were not directly analysed for the well-known arguments of the lunar theory, but for arguments of a fictitious period, always taken as commensurable with the lunar day. If any real inequality had a slightly different period from the fictitious argument, the fact would be disclosed by a gradual change of phase. Thus, if a sufficient number of auxiliary arguments is employed, no periodic error of sensible magnitude that really exists can escape detection. A full description of the method, together with the analysis for 145 terms in the Moon's longitude, is given by Dr. Cowell in vol. lxv. p. 108 of the *Monthly Notices* of the Society, and a coefficient is inferred from the observations for every periodic term of the Moon's longitude.

The author then gives a comparison of his results with Hansen's coefficients when the latter are supplemented by the planetary terms calculated by Radau, and by Hill's terms, dependent on the figure of the Earth. This comparison shows that, with a few exceptions, the coefficients derived from the above-mentioned gravitational calculations are in close agreement with our Medallist's results derived purely from observation. These exceptions occur chiefly in the terms into the determination of which the Moon's semidiameter enters, viz. the Parallactic Inequality and the Variation.

The practical difficulty in determining these terms consists, as is well known, in the changes in the apparent semidiameter of the Moon, produced not only by the state of illumination of the background of the sky, but by the considerable variety in the personal equation of the observers when observing opposite limbs. Dr. Cowell has assumed that, in the mean of many observers, this personality may be assumed a constant, and he therefore introduces the semidiameter of the Moon as an unknown constant in his analysis of the observations, and finally obtains a value for the Parallactic Inequality (*M.N.*, lxiv. p. 585), which corresponds with $8''{\cdot}787$ for the solar parallax, with an apparent probable error of $\pm 0''{\cdot}007$, to which, for the above reasons, he assigns a real uncertainty of $\pm 0''{\cdot}02$. Within this uncertainty the result is in agreement with the best astrometric determinations of the solar parallax.

Having regard to this uncertainty, it will always be better to derive the Parallactic Inequality by the reverse process, viz. from the independently determined value of the solar parallax, and its theoretical relation to the Parallactic Inequality, notwithstanding that an error of $\pm 0''{\cdot}01$ in the adopted value of the solar parallax will produce an error of $\pm 0''{\cdot}14$ in the value of the Parallactic Inequality.

The Variation can be independently determined from theory with far greater accuracy than by its direct measurement—the latter being even more affected by change of illumination of the sky and personality than in the case of the Parallactic Inequality.

The chief further exception, and an interesting proof of the accuracy and efficiency of Dr. Cowell's work, is afforded by the Jupiter Evection term, which was discovered empirically by Newcomb in 1876, and afterwards correctly attributed by Nevill to the action of Jupiter. Hill and Radau agreed, by different methods, in assigning the value 0″·9 to the coefficient. Our Medallist obtained, from his discussion of observations, the value 1″·1, and subsequently both Newcomb and Brown derived exactly Cowell's value, 1″·1, by theory.

A further very interesting outcome of this comparison is to bring into strong light the excellence of Monsieur Radau's work, for Dr. Cowell finds that there is not a single non-solar term of short period that can be derived from the observations which is not represented by one of M. Radau's theoretical terms.

In a manner similar to that of his investigation of the Moon's longitude, our Medallist has dealt with the Moon's latitude (*loc. cit.*, lxv. p. 721), where his coefficients are directly compared with those of Brown's New Lunar Theory, which had meanwhile been published.

The agreement between the values is remarkable.

Although Dr. Cowell confines his statement of these values to the nearest tenth of a second of arc, there are only six cases, among the 95 coefficients compared, in which the difference "Brown – Cowell" rises to that amount, and of these the largest is 0″·13. The mean of the 95 differences taken without regard to sign amounts only to 0″·036.

So far as constants like the Inclination and Excentricity are concerned, which can only be determined from observation, and are independent of theory, Dr. Cowell's results are the most reliable that have yet been derived (*M.N.*, lx. pp. 564 and 745). But in other respects it must be clearly understood that this statement is not intended to convey that our Medallist's results are to be regarded as a proof of the accuracy of Brown's lunar theory. That theory, from the completeness of its development, from the numerous independent checks and methods of control employed, and from the exhaustive examination of every detail of its construction, must rather be regarded as the standard with which our Medallist's results should be compared; and we have seen how well they bear that test. Indeed, if Newton's law of gravity is rigorously true, and if there are no other forces at work, Brown's lunar theory must be regarded as exact, far beyond the power of observation to detect the errors of its separate coefficients, at least in so far as the terms of short period are concerned. Thus, with Brown's Tables and for such a period as a year, the discordance between the tabular and observed place of the Moon will, apart from a constant difference, be most probably but a mere representation of the errors of observation. But for long periods of time this will not be the case, because, as is well known, some of the long-period terms remain unexplained by theory. Thus, although the discordance between the theory and observation may probably be regarded as practically

constant during a single year, there will probably be a mean outstanding annual discordance, varying slowly from year to year.

The series of papers, in which Dr. Cowell deduced from modern observations different terms in the Moon's longitude, left untouched the question of the secular acceleration of the Moon's mean motion. In fact, Dr. Cowell had shown (*M.N.*, lxiv. pp. 35, 53) that any value for the secular acceleration could be satisfied by modern observations, if corresponding corrections were introduced into the mean longitude at epoch, the centennial motion at epoch, and the larger empirical term of long period. If, on the other hand, the secular acceleration could once be determined, no larger error in the remaining terms would be possible. In order, therefore, to complete the empirical determination of the elements of the Moon's motion, it was necessary to seek evidence for secular acceleration which should be independent of the possible errors in the other terms.

Like many of his predecessors, Dr. Cowell found such evidence in the records of ancient eclipses of the Sun. The magnitude of a solar eclipse at a given place depends, in the main, on the relative positions of the Sun, the Moon, and the Moon's node; and in the case of an ancient eclipse, the combined effect of the possible errors in the other terms is much less than that of an error of 1″ per century in the accelerations. In *M.N.*, lxv. pp. 861–7, Dr. Cowell investigated five ancient solar eclipses, and found that he could satisfy them all by assuming certain corrections to the secular accelerations of the Moon's longitude and node, without assuming any correction to the values obtained by theory or modern observation for the remaining terms in the Moon's motion.

In answer to a theoretical objection to his correction to the acceleration in the longitude of the node as measured from the equinox, Dr. Cowell shortly afterwards (*M.N.*, lxvi. pp. 3, 4) substituted for this a corresponding correction to the longitude of the Sun and Moon. As the eclipses afford no data for determining the position of Sun and node in relation to the equinox, but only in relation to one another and to the Moon, this correction equally satisfied the data supplied by the solar eclipses. In this way Dr. Cowell obtained his final values of +10″·9 for the secular acceleration of the Moon, and +4″·1 for the secular acceleration of the Sun. This conclusion is independent of any theoretical explanation of these accelerations, but in *M.N.*, lxvi. pp. 352, 355, Dr. Cowell provided a tentative explanation of an apparent secular acceleration of the Sun as the effect of tidal action on the Earth's axial rotation.

No previous solution had met with the same success as Dr. Cowell's in satisfying ancient solar eclipses without assuming impossibly large errors in the mean motion of the Moon and her node, as deduced from modern observations. By assuming a secular acceleration of the Sun, Dr. Cowell successfully met this difficulty. This assumption has, however, been challenged, partly

on the ground of the vagueness of the records on which it rests, and partly on the ground that it is supposed in some quarters to be inconsistent with modern observations. That the question is complicated by the vagueness of the historical evidence is undoubted, but the complete failure of the existing tables to satisfy the records of ancient eclipses seems to show that some correction is necessary, and it is difficult to find a correction of sufficient magnitude except in the two terms to which Dr. Cowell has applied his correction. More recently, Dr. Fotheringham has (*M.N.*, lxix. p. 469) suggested values for the accelerations of the mean motion of the Sun and Moon which come nearer to the values adopted in the existing tables, and which also satisfy a series of ancient eclipses. It is hoped that the question may be set at rest by the Babylonian eclipse observations collected by Father Kugler, whose monumental studies in Babylonian Astronomy have already thrown so much light on the history of science.

Without entering into further details of the researches of our Medallist on the motion of the Moon, let us turn now to the eventful years of his labours in connection with the 8th Satellite of Jupiter and Halley's Comet.

After a search extending over three successive oppositions of Jupiter, Mr. Melotte, of the Royal Observatory, Greenwich, on the 28th February 1908, detected on a photographic plate a very faint object, which he succeeded in identifying and tracing back as far as January 27 of the same year on a series of 8 plates which had been taken during that interval. The total motion in the interval was shown to be $+70^{s}\cdot58$ in R.A. and $+11'\,32''\cdot9$ in declination. Mr. Melotte's admirable persistence and acumen in this discovery were, as we all know, worthily recognised by the award of the Jackson-Gwilt Medal to him in 1909. The discovery was announced in the *Monthly Notices* for March 1908, but the material then available was insufficient to prove whether the object was a new satellite of Jupiter or a minor planet.

Three farther observations were secured, viz. on March 27, 31, and April 3 (*loc. cit.*, April), and finally one on April 24.

The primary difficulty in dealing with such observations is to determine the distance in the line of sight, *i.e.* to decide not only whether the object is a minor planet or a satellite of Jupiter, but, if the latter, whether at the time of observation it was on the nearer or farther side of the planet. With remarkable acumen, Dr. Crommelin perceived that if the object was a satellite of Jupiter with direct motion, its period of revolution would be about four years, and such a period would probably be incompatible with a stable orbit—he being guided to this latter conclusion by inspection of Hill's "variation curves" for Moons of various lunations.

When the equations of motion had been formed and a solution was being sought by trial and error, Dr. Crommelin's hypothesis was first tried, and a retrograde orbit was found and compared with the above-mentioned observations. The agreement was so satisfactory that it seemed unnecessary to examine the alternatives of

direct satellite or planetary motion; any vague misgiving on the subject was set at rest when the satellite was again detected, nearly in its predicted position, on a plate taken in February 1909. The calculation of the motion of the satellite presented peculiar difficulties because of the large departure from an elliptic orbit produced by the action of the Sun; in fact, during the period under consideration, the disturbing force of the Sun ranged from 6 per cent. to 10 per cent. of the attraction of Jupiter.

The orbit, besides being retrograde, was excentric, and highly inclined to the plane of Jupiter's path, so that the formulæ of Delaunay's lunar theory, which otherwise would have been available, were not sufficiently convergent for application.

The solution which Dr. Cowell evolved is so original, so practical, and of such high promise of value to the future of Astronomy that it forms a large part of the grounds of the Society's award to-day. That solution is given in a joint paper by Messrs. Cowell and Crommelin (*Monthly Notices*, June 1908).

In principle it may be put thus:—

Suppose that by any process the rectangular co-ordinates of a moving particle are known at three epochs,

$$n-2t,\ n-t, \text{ and } n,$$

and that the attracting masses and their co-ordinates for these epochs are also known, it is required to find the co-ordinates of the particle for the epoch $n+t$. Let the co-ordinates for these epochs be x, y, and z,—distinguished for the four epochs by corresponding suffixes. All the requisite data being known for the first three epochs, the corresponding accelerations of the particle for each of the co-ordinates and for each of the epochs can be rigorously computed by Newton's law of gravitation, but they cannot be rigorously computed for the epoch $(n+t)$ because the co-ordinates for that epoch are unknown. Since, however, a small error in the co-ordinates produces a comparatively insignificant error in the acceleration, it is generally possible, by extrapolation, to make so close an approximation to their true values as to render a second computation of the acceleration unnecessary. Thus if X_{n+t} is the acceleration for x_{n+t} it is easy to show that, if the interval t does not exceed certain limits, the second difference of the x co-ordinate will, with nearly sufficient accuracy, be $X_n + \frac{1}{12}$ of the second difference.*

Since the first and second differences are known from the co-ordinates of the epochs $n-2t$, $n-t$, and n, approximate values

* If the usual differential equation of motion

$$\frac{d^2x}{dt^2}=X$$

is thrown into a form suitable for finite intervals of time, we have—

The 2nd diff. of the x co-ordinate will be $X+\frac{1}{12}$ (the 2nd diff. of X).
$-\frac{1}{240}$ (the 4th diff. of X).
$+\frac{1}{10\,080}$ (the 6th diff. of X).

of x_{n+t}, y_{n+t} and z_{n+t} are easily obtained. With these co-ordinates the values of X_{n+t}, Y_{n+t} and Z_{n+t} are computed.

Should the resulting values of x_{n+t} etc. not coincide sufficiently with the values of the co-ordinates employed in computing the acceleration, the values of X_{n+t} etc. can be corrected by recomputation with the corrected co-ordinates

If the interval t is not too long, it will generally be found that the error in the prediction is not large enough to affect the calculation of the attractions. The practical point is therefore to steer a middle course in choosing the time-interval. This interval must not be so long as to render the prediction of the co-ordinates next in order too uncertain, and it must not be so short as to multiply unnecessarily the number of steps that are required.

Assuming now that three complete observations in R.A. and Dec. of a satellite have been obtained at three equidistant epochs, we have the data necessary to determine the six arbitrary elements of the orbit. If the intervals are not equal, then by a little interpolation amongst the observations we may be able to assume that the observed geocentric angular positions are known for the epochs $n-t$, n, and $n+t$.

We have now to supplement these geocentric angular positions by distances in the line of sight. The three unknown distances may be reduced to one if we take the direction of our co-ordinate x at right angles to the line of sight for the epochs $n-t$ and $n+t$. There then remains only one unknown quantity to be eliminated from the equation by a process of trial and error.

The co-ordinates of the satellite being now known for three intervals of t, the co-ordinates can be computed for successive intervals by the process already described.

The beautiful and interesting results of this investigation were well illustrated by a model exhibited at a recent meeting of the Society.

To some extent a departure from historical sequence has been made by describing Dr. Cowell's work connected with the 8th satellite of Jupiter before his researches on Halley's Comet; but the reason for that departure will soon be apparent. In December 1906 (*M.N.*, lxvii. p. 137) there appeared a very interesting paper by Dr. Crommelin, entitled "Note on the approaching return of Halley's Comet," in which the author draws attention to a paper published by Dr. A. J. Ångström in 1862, entitled "Sur deux inégalités d'une grandeur remarquable dans les apparitions de la Comète de Halley" (*Actes de la Société Royale des Sciences d'Upsal*, sér. iii., t. iv.). In this paper Dr. Ångström discusses the observed perihelion passages as determined by Dr. Hind from B.C. 11 to A.D. 1835, and finds a mean period for the comet of 76·93 years, this period being affected by two large inequalities with amplitudes of 1·5 years and 2·3 years, having periods of 2650 and 782 years respectively. The arguments were based on theory, the amplitudes on observation, and the resulting curve satisfied all the returns of the comet to perihelion within a year.

Dr. Ångström did not claim that these are the only inequalities, but merely that they are the most important ones.

Dr. Crommelin then goes on to point out that whereas Ångström's curve indicates 1913·08 as the time of next perihelion passage of the comet, that given by de Pontécoulant from a detailed computation of the perturbations is 1910·37—a discordance of 2·7 years. He makes an appeal to some mathematician, with the necessary leisure and ability, to undertake an independent computation of the perturbations.

"Before the return of Halley's Comet in 1835 there were at least five independent computations of the orbit—those of Damoiseau, Pontécoulant, Lehmann, Rosenberger, and Lubbock; and it is difficult to understand why an equal amount of interest is not shown in the approaching return." He concludes his paper as follows:—"Assuming that the date 1910 May is correct for the perihelion passage, I think the complete failure of the Ångström curve is not without a warning to us. We have here a curve which admirably fits 25 successive passages, and yet the first time that it is used to predict a return it breaks down utterly, the error being almost three years, or three times the largest previous error. This is decidedly a startling fact, and indicates the danger of using terms of an empirical nature in lunar and planetary tables. Where such are used, it is at least desirable that means should be provided for readily effecting their removal from the calculated positions."

About the same time Dr. Crommelin approached Dr. Cowell on the subject, and urged him to take up the work, and this Dr. Cowell consented to do provided that Dr. Crommelin would assist him. At the time Dr. Crommelin was responsible for the reductions of the altazimuth observations at Greenwich, so that he could give but part of his time during the day to the work of Halley's Comet, and it was very largely by devoting his spare time to it at night that he was able to give the very considerable amount of assistance that he did to Dr. Cowell.

At first the research was confined to a revision of Pontécoulant's work. In a series of papers published in the *Monthly Notices* of the Society, Cowell and Crommelin successively replaced portions of Pontécoulant's work by their own, so that, as the calculations proceeded, a series of different dates for the time of perihelion passage was arrived at. When Pontécoulant's work had been entirely replaced, the date of perihelion passage in 1910 was found to be April 13th. Although this revision had led to a prediction which, according to previously accepted methods of treatment, appeared to be complete, our Medallist was convinced that it was unsatisfactory, and should be replaced by one of a more rigorous character. The reasons for this conclusion are stated as follows in the authors' joint memoir on the subject:—

"Rosenberger showed clearly that, to secure accuracy, it was necessary to frequently rectify the orbit, in order to prevent the elliptical path from diverging widely from the actual path of the

comet. Now, this frequent rectification is an exceedingly troublesome process, and does away with much of the advantage that there is in assuming that the comet is moving in an ellipse; hence it was decided to discard the elliptical hypothesis altogether, and to proceed by mechanical quadratures. This requires the knowledge of the comet's rectangular co-ordinates on two given dates."

The next question, therefore, was to consider how these two initial positions could be arrived at with sufficient accuracy, because very small errors in their adopted co-ordinates would produce great errors in the resulting period of revolution, and even errors in the computed perturbations.

Westphalen (*Ast. Nach.*, vols. xxiv. and xxv.) had very completely discussed the best of the numerous observations of the comet made at its apparition in 1835, and the orbit which he derived represented these observations very accurately. He had made no attempt to redetermine the mean motion (or its equivalent, the semi-major axis); having provisionally accepted for that element the value of Rosenberger-Damoiseau, he had derived all the elements of his orbit in terms of an undetermined quantity Δa, which he adopted as one hundred times the correction required by the assumed semi-major axis of the orbit. In order to arrive at a nearly accurate value of this Δa, Cowell and Crommelin recalculated provisional perturbations for the revolution preceding 1835, and so derived from comparison with the known epoch of perihelion passage in 1759 a more accurate value of the mean motion, and thence of Δa.

With Westphalen's elements thus corrected, the rectangular co-ordinates of the comet for the epochs 1835 November 16·0 and 1835 November 18·0 were computed as the origin of the subsequent mechanical quadratures. To give some idea of the precision required in the determination of these two fundamental points of origin, it may be of interest to state here that an error of unity in the last figure of the 8th decimal place of the astronomical unit in the length of the chord joining these points of origin would produce an error of one day in the period of revolution of the comet.

Accordingly, in the final work, no less than 11 decimal places of the astronomical unit were employed in the computations of the co-ordinates near perihelion. In other words, distances of little less than 5 feet in the successive intervals of the comet's path and in the comet's distance from the Sun were rigorously taken into account!

It could not, of course, be assumed that the original co-ordinates were correct within such limits. The only available test of their accuracy was to take them as origin and compute the positions of the comet backwards from 1835 to 1759, and forwards to 1910, by the rigorous methods of mechanical quadrature which have been already described in connection with the investigation of the orbit of Jupiter's 8th satellite. This has been done by our Medallist, with the whole-hearted assistance of his colleague

Dr. Crommelin; their definitive results, which I have been privileged to see in proof, will shortly appear as a part of the Greenwich publications.

The results are, that by computing backwards they found the predicted perihelion passage of 1759 would be only half a day later than the observed passage, but that the time for the perihelion passage of 1910 would be two and a half days earlier than observed.

The authors of the paper are confident that this discordance of two and a half days between the predicted and observed times of perihelion passage in 1910 cannot be accounted for by errors of computation or the action of any known forces. Had the discordance been alone due to errors in the co-ordinates of origin in 1835, then it does not seem possible that the computed time of perihelion passage could be half a day too late in 1759, and yet be two and a half days too early in 1910.

It is true that, immediately before and after the perihelion passage of 1835, the comet made very close approaches to Jupiter —one on its return, and one on its outward path, passing on both occasions within about 1·6 astronomical units of the planet. On the earlier of these occasions the action of Jupiter accelerated the mean daily motion (47″) of the comet by 0″·67, on the later occasion by 1″·08.

The combined effect is to render the revolution that began in 1835 3 per cent. (or 800 days) shorter than the revolution which ended in 1835. But the mass of Jupiter seems to be accurately known within one three-thousandth part of its amount, so that no error in the computed perturbations amounting to three days can be attributed to an error in the assumed mass of Jupiter.

Thus, unless there be a planet beyond Neptune which made a near approach to the comet between 1835 and 1910 (a circumstance, however, of great improbability when we consider the considerable inclination of the path of the comet to the ecliptic), we are driven to the conclusion that the discrepancy of three days must be due to some other cause than gravitational attraction.

Dr. Backlund, in his investigations on the motion of Encke's Comet, has found abrupt acceleration of its mean motion at certain points of some of its revolutions. It is not impossible that like causes have been at work to account for the irregularities in question in the motion of Halley's Comet, but no data at present exist on which to found a definite opinion as to what these causes are.

As the papers connected with Halley's Comet have been published in the joint names of Cowell and Crommelin, it is but justice to both to mention their respective shares in the work, and I do so now, unreservedly, with their mutual concurrence. We cannot forget that it is to Crommelin that the work owes its inception, for without his initiative and zeal it is doubtful whether our Medallist would have turned his attention at the time to the subject. Dr. Crommelin also took a large personal share in the

computation of the work under consideration. The whole of the computation and identification of the returns of Halley's Comet previous to 1378 was due to Dr. Crommelin. It is a most important and interesting research, and one only possible to a man of his devotion and widely intimate knowledge of astronomical literature. It should be mentioned, however, that for the more easy calculation of perturbations Dr. Cowell devised a method of splitting up the disturbing function into two parts, one of which can be integrated, and the other is almost negligible during the outer half of the orbit (*i.e.* for about nine-tenths of the period of revolution), and this device has greatly facilitated Dr. Crommelin's work in tracing backwards the path of the comet to B.C. 240. Briefly, it may be stated that whilst Dr. Crommelin has taken the large share of the work which is already mentioned, in which he had the assistance of Messrs. Cripps, Smart, and T. Wright, all that is new in the mathematical methods employed and in the arrangement of the work of computation is due to Dr. Cowell.

To pass now in summary to the grounds of our award to-day. Science is indebted to Dr. Cowell, first of all, for the researches on the motion of the Moon, which form one ground of our award, and I venture to think that in accuracy and importance they bear favourable comparison with previous researches of a like character, for which alone the Society has conferred its medal.

Farther, we owe to him another boon, viz. practically a new method of orbit computation, which must be of very great ultimate service to astronomy. The remarkable feature of the matter is that the process of mechanical quadratures is as old as Newton, but the simple and apparently obvious manner of performing it which Dr. Cowell has applied seems never to have before occurred to astronomers, or, at all events, has never been similarly employed by them for a like work. In some degree it is the old story of Columbus and the egg over again. But it required the man with the peculiar attributes of Dr. Cowell, to which we have already referred, to face a work of such apparently forbidding aspect; only such a man could in advance see, through the mass of figures involved, the simple and ready way of arranging the computation in so straightforward a form that the subsequent work could be done by any skilled arithmetical computer.

I am given to understand that Dr. Cowell is now engaged in still farther simplifications and improvements of his method. Of course the smallest error committed at any period of the calculation would be carried forward into every subsequent stage of the work, entirely vitiating the accuracy of the result; and therefore, only by perfectly systematic arrangement and ingenious devices of control, such as were evolved by Dr. Cowell, could all error be avoided and the method become a practical one.

An interesting proof of the practical advantages of the method is afforded by the following facts. After Dr. Cowell had resolved to apply his process to the computation of the orbit of Halley's

Comet, he was closely occupied for two months in arranging the methods of control, and the most simple and labour-saving forms of computation. When this had been done, the whole of the actual computation for two revolutions of Halley's Comet was begun and ended within ten weeks! No astronomer, so far as I am aware, has ever accomplished a like work in a like short period of time. Dr. Cowell assures me that the amount of arithmetic involved is actually less than that required by the less rigorous method of disturbed elliptic motion, whilst this rigorous method of his is free from the mental strain and possible mistakes involved in frequent rectification of an assumed elliptical path.

Thus, not only by his important researches in the motion of the Moon, but by bringing the application of mechanical quadratures into a convenient and practical form, and applying that process to the solution of such interesting and difficult problems as the motion of Jupiter's 8th satellite, and the accurate prediction of the return of Halley's Comet, Dr. Cowell has rendered services of very great value to astronomy.

Dr. Cowell,—Allow me, therefore, the pleasure of handing to you, on behalf of the Royal Astronomical Society, its Gold Medal, the highest token of its esteem of your labours which it is in the power of the Society to bestow. Let me couple with this award an expression of our earnest hope that you may long be spared with health, strength, and opportunity to prosecute these researches which are so perfectly adapted to your genius and inclination, and which are so conducive to the progress of the Science for the promotion of which this Society was founded.

Like my predecessor in this chair, I now venture to claim your indulgence for what, but for his excellent example, would have been a departure from precedent. He claimed, with universal concurrence, that the President, after delivery of the usual address in presenting the Medal, "might"—I use his own words—"with advantage make the Annual Meeting an opportunity for a brief address on some subject of his own choosing, provided that we could avoid stereotyped action, which might easily come to impose an unnecessary tax, not only on the President in the preparation of such an address, but also on the Society in listening to it."

By delivering no appendix to my address of last year, I trust that I have avoided the establishment of any stereotyped action of the kind which Mr. Newall so properly deprecates. But I feel on the present occasion that there remains something of my own choosing to be said which may be more appropriately spoken now than during the normal address devoted to explanation of the ground of the Medal-award.

That "something" consists of two or three subjects, connected with what may be termed the future practical policy in some

departments of Astronomy in England, which arise out of the subject-matter of the address.

The time seems to be peculiarly fit for consideration of these questions because of the changes which have so recently taken place in our two chief British National Astronomical Establishments—the Royal Observatory, Greenwich, and the Nautical Almanac Office. The first of these considerations is based on the question as to what action, if any, should arise out of the probable fact that Professor Brown's new lunar theory is exact in a degree far beyond the power of observation to detect the errors of its separate coefficients, at least so far as the terms of short period are concerned,—a fact that, as I have shown, is strongly corroborated by our Medallist's discussion of the long series of Greenwich observations from 1750–1910.

It is all but certain that, for such periods as a year, the discordance between observation and Brown's Tables of the Moon will, apart from a small and practically constant difference for the year, be but a mere representation of the errors of observation.

Of course, as is well known, this mean annual difference will vary slowly from year to year, because of some of the long-period terms which remain unexplained by theory.

May one not, therefore, reasonably raise the question whether in future it is necessary to do more than provide, in the simplest effectual manner, for determining the mean annual discordance between theory and observation. For this purpose a moderate number of meridian observations of the Moon, fairly distributed between first and second limb, would amply suffice, provided that in determining the mean value of (C − O) for the year an equal weight is given to the observations of each limb.

So far as our present knowledge goes, the terms of short period, as already mentioned, have been theoretically determined by Brown with a precision that cannot be emulated by direct observation; and if that is assuredly the case, there can be no doubt that the present laborious and costly series of observations of the Moon may, without detriment, be very considerably limited.

Although it is perhaps difficult to imagine that the unknown causes which give rise to some of the long-period inequalities in the Moon's motion can also produce sensible inequalities of short period, it is by no means impossible that these unknown forces may sensibly affect the constant of the inclination.

It seems, therefore, undesirable as yet to modify the regular programme of meridian observation of the Moon which has been so long a leading and honourable feature in the work of Greenwich Observatory, although it is doubtful whether such observations should be made except when the background of the sky is dark—because of the variation from normal apparent diameter in daylight or strong twilight.

If our knowledge of the Moon's physical libration can be regarded as satisfactory, it appears probable that the observation of such well-determined points on the Moon's surface as Mösting A

might with advantage be substituted for meridian observations of the limbs. The discordance between the results of Franz and Hayn may perhaps throw some doubt upon the accuracy of our present knowledge of the coefficients of the physical libration, but Stratton's recent rediscussion of Schlüter's observations appears to confirm the accuracy of Franz's coefficients.

Professor E. W. Brown is of opinion that a series of observations extending over nineteen years is required to improve our existing knowledge of the libration. Our Secretary, Mr. Saunder, has pointed out that there already exists at Paris a series of photographs of the Moon, of great perfection, extending over seventeen years, and Monsieur Baillaud has cordially consented to its continuation for two years more.

We know, from the results recently communicated to the Society by Mr. Saunder, the great accuracy attainable in determining the relative co-ordinates of points on the Moon's surface from these photographs, so that the means are in sight for a definite determination of the coefficients of the Moon's physical libration.

The series of meridian observations of the Declination of the Crater Mösting A, recently completed at Greenwich and the Cape, will throw useful light on the probable comparative accuracy of observations of such an object and observations of the limbs.

But be that as it may, I venture to express the view that the extra-meridian observation of the Moon with the altazimuth should be discontinued, for the following reasons:—

(1) So far as I am aware, these observations have not been employed with advantage by anyone who has occupied himself in the discussion of the motion of the Moon.

(2) For various reasons, which need not here be entered upon, the results, at least with the old altazimuth, are of inferior accuracy to those obtained with meridian instruments—and their reduction is exceptionally laborious.

(3) In the present state of the lunar theory they are unnecessary.

I venture to think it is otherwise with occultations. Well-observed occultations are probably those which are best of all suited for the determination of long-period and secular terms. The results are less affected than any other—at least when they occur at the dark limb—by personality, and especially so by that part of the personality which depends on the quality of the illumination of the background of the sky. It is true that in reappearances there is always the danger, when the eye is not directed to the exact point of reappearance, that the observer may mistake his first sight of the star for its true reappearance, and for this reason it is most desirable that every observation of a star's reappearance should, as far as possible, be checked by the independent observations of two or more observers. If this feature of occultation-observation is attended to, and if care is taken that the places of all occulted stars are well determined at several observatories, we shall provide our successors with a series of results which they may reasonably regard

as the most reliable of all for their farther researches on the motion of the Moon. This is a work in which every observatory can easily share.

It is quite true that irregularities of the Moon's limb produce accidental errors in determining the position of the Moon's centre which are systematic so far as independent observations at a particular observatory are concerned; but such errors become purely accidental when the occultation of the same star is observed at different observatories, or when a number of different phenomena have been observed. The small amount of personality and the great precision of the results, when obtained with the above-mentioned precautions, have been recognised by Newcomb.

I venture to think that the time has come when an organised search should be made for records of good observations of occultations in the past. Newcomb has already done much in this respect. Care should also be taken to collect all reliable observations of occultations as they are made, and that provision be made for their systematic reduction and comparison with Brown's tables, as well as for their publication in a convenient and practical form.

These are questions which I would venture to suggest as worthy of full consideration at the present juncture.

I turn now to a matter which appears to be of great importance at the present moment. We have three national establishments devoted to the promotion of Astronomy and Navigation, and which, most appropriately, are administered under the Admiralty, and provided for under the vote for Scientific Services in the Navy-estimates. These establishments are the Royal Observatories at Greenwich and the Cape, and H.M. Nautical Almanac Office. Now the three great subdivisions of Astronomy are Astrometry, Astrophysics, and Astrodynamics. The observatories at Greenwich and the Cape have to deal with the two first named of these departments, and are equipped for work in those fields of research, but there is no national provision whatever for work in the department of Astrodynamics. The functions of the Nautical Almanac Office are at present limited to the more or less mechanical production of the Nautical Almanac; in other words, to the calculation and publication of the ephemerides of the Sun, Moon, planets, and principal fixed stars, and the phenomena of eclipses, satellites, etc., from existing data.

But the outside world does not understand that between the observations of celestial objects and the calculation of astronomical ephemerides and phenomena there lies the work of the department of Astrodynamics, viz. the creation of the tables upon which the Nautical Almanac relies for the predictions which it publishes. Whence, then, come the tables which are employed for the purposes of the Nautical Almanac? For the places of the Moon are employed the Tables of Hansen of Gotha, derived and calculated by that great geometer fifty years ago, and modified by empiric corrections derived by Simon Newcomb of Washington from comparison with observation. These tables will, no doubt,

ere long, be replaced by those of Brown, to which reference has already been made; and these are the product of British brains and American money. For the tables of the Sun and planets, the Tables of the great French geometer Le Verrier were, until recently, employed, and are now replaced by the Tables of Newcomb and Hill, computed under the direction of the former in the American Nautical Almanac Office.

For the tables of Jupiter's satellites, the Tables of the French geometer Damoiseau, modified and extended by Adams of Cambridge, have up to the present time been employed; but these, we hope, will shortly be replaced by those of Professor Sampson of Durham, now Astronomer Royal for Scotland.

May not one, therefore, reasonably ask whether it is creditable to British astronomical science that we have no establishment for the prosecution of Astrodynamics?

Whilst Astrometry and Astrophysics are officially recognised and followed at Greenwich and the Cape, should not the Nautical Almanac Office be the head and centre of Astrodynamics in this country?

I am very far from suggesting that our Nautical Almanac Office should be called upon to do what Simon Newcomb actually did, viz. to prepare new tables of the Sun and planets for its own particular use; still less to attempt, what he attempted to do, and would have done had life been spared him, viz. provide new tables of the Moon also.

These are supreme efforts which it is not for ordinary mortals to attempt, and which it is hardly advisable for any man to attempt, because such over-ambitious schemes are apt to lead to over-haste, and consequent imperfect work.

Besides, since science knows no nationality, it is reasonable that such work as this, as in other departments of science, should be shared amongst the nations, and that each great nation should take its share in it.

Now it so happens that we in England are at the present moment in a peculiarly favourable position for taking a step in this direction. I do not think it any breach of confidence to state that one of the chief reasons which induced Dr. Cowell to accept the position of Superintendent of the Nautical Almanac Office was the hope and the desire to make that office what it should be, viz. the head and centre of practical Astrodynamics in England.

The object of these remarks is, if possible, to aid in the realisation of that most reasonable hope and that most laudable desire.

No over-ambitious project is aimed at, for new tables of the Sun, Moon, and planets are not at present required. But the creation of perfect tables depends very largely on the perfection of the Constants of Astronomy, such as the masses of the planets, etc., and there are other numerous researches which demand prosecution before future advance can be looked for.

By way of example, one most desirable research would be to apply Cowell's quadrature method to prediction of the path of Eros

at its favourable opposition in 1935, and, by a subsequent discussion of its orbit, to determine the mass of the Earth, whose attraction causes large perturbations in the orbit of Eros.

Another most important research would be the discussion of the orbit of Jupiter's 8th satellite, and the determination of the mass of Jupiter from that discussion.

A most interesting question in Astrodynamics would be a discussion of the orbits of the minor planets which have the same mean motion as Jupiter.

Besides, there are always comets turning up, presenting interesting questions in Astrodynamics which such an office should deal with.

For these things our present establishments do not provide, and it is most desirable that England should not be left entirely behind in such matters. What, then, is involved in the establishment of such an Office? It is not a serious matter.

The existing establishment for the production of the Nautical Almanac need not be disturbed in the slightest degree, nor the prospects of its existing subordinate officers be changed.

What is required is simply an additional assistant, say a carefully selected Isaac Newton student, or a man of like mathematical acquirement and turn of mind, who might be induced to accept the post with the prospect of becoming Dr. Cowell's successor, and, say, two or three additional arithmetical computers. This is a small demand to make in order to fill a great need in British Astronomy. I make the proposal entirely on my own responsibility, and leave it meanwhile in the hands of the Society.

If these suggestions bear fruit, I could feel that, however unworthily I may in other respects have filled this chair, I had not done so entirely in vain.

The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected :—

President.

F. W. Dyson, Esq., M.A., F.R.S., Astronomer Royal.

Vice-Presidents.

Sir W. de W. Abney, K.C.B., R.E., D.C.L., F.R.S.
E. B. Knobel, Esq.
W. H. Maw, Esq., LL.D.
H. H. Turner, Esq., D.Sc., F.R.S., Savilian Professor of Astronomy, Oxford.

Treasurer.

Major E. H. Hills, C.M.G.

Secretaries.

A. R. Hinks, Esq., M.A.
S. A. Saunder, Esq., M.A.

Foreign Secretary.

Sir David Gill, K.C.B., LL.D., D.Sc., F.R.S.

Council.

Sir W. H. M. Christie, K.C.B., M.A., D.Sc., F.R.S.
P. H. Cowell, Esq., M.A., D.Sc., F.R.S., Superintendent of the Nautical Almanac.
A. C. D. Crommelin, Esq., B.A., D.Sc.
A. S. Eddington, Esq., M.A., M.Sc.
Alfred Fowler, Esq., F.R.S., Assistant Professor of Physics, South Kensington.
J. W. L. Glaisher, Esq., Sc.D., F.R.S.
E. W. Hobson, Esq., Sc.D., F.R.S., Sadlerian Professor of Mathematics, Cambridge.
H. P. Hollis, Esq., B.A.
Thomas Lewis, Esq.
H. F. Newall, Esq., M.A., D.Sc., F.R.S., Professor of Astrophysics, Cambridge.
Rev. T. E. R. Phillips, M.A.
F. J. M. Stratton, Esq., M.A.